THE AMERICAN JOURNAL OF ROENTGENOLOGY AND RADIUM THERAPY

VOL. 44 OCTOBER, 1940 No. 4

ROENTGENOLOGY OF PANCREATIC DISEASE

CALDWELL LECTURE, 1939*

By JAMES T. CASE, M.D., D.M.R.E., F.A.C.S.
Professor of Radiology, Northwestern University Medical School
CHICAGO, ILLINOIS

AS WE ASSEMBLE for the twentieth time to pay our respects to the memory of the pioneers of this Society who have made outstanding contributions to the development of medical reontgenology, it is fitting that for a few moments we recall the origin of the event and why Eugene Wilson Caldwell's name was selected to designate the annual lecture.

I find many of our members unacquainted with the importance of Caldwell's work, unaware of the fact that he was one of the martyrs to the early ignorance of the dangers attending the use of the roentgen rays, and that he died in military service; and yet it is not surprising that these things should not be familiarly known, for since 1918 when this distinguished roentgenological leader died there have been admitted to this Society's roll the names of approximately 320 new members, the majority of whom never had the privilege of seeing or of receiving inspiration from personal contact with this man who did so much to develop modern roentgenological apparatus and to place the practice of roentgen diagnosis and therapy upon a high plane as a medical specialty.

Caldwell contributed much toward the conquest of many mechanical and technical difficulties which beset the earlier workers in roentgenology, but there are many illustrious American pioneers in roentgenology to whom every member of this Society is indebted, as was pointed out by the late Preston M. Hickey, whose own life and work with equal justice merit a lasting memorial.

I have often heard our best speakers attempting to expound in fifteen or twenty minutes a valuable lesson which by lack of adequate time was set forth only fragmentarily and hastily, and I used to imagine how wonderful it would be to give at least one speaker all the time desired, without interruption of gavel or gong, to deliver his valuable lesson. When speakers are limited to a certain few minutes they seldom fail to show it by too rapid delivery, spotty selections from their prepared paper, and with a certain nervousness betraying the evident intention of complying with the chairman's injunction not to overrun the allotted time.

In 1920, when as President-Elect it devolved upon me to arrange the program and to preside over the annual meeting, I realized that I had it in my power to experiment with such an idea. Accordingly after consultation with the other officers of the

* The twentieth Caldwell Lecture, delivered at the Fortieth Annual Meeting of the American Roentgen Ray Society, Chicago, Ill., Sept. 19–22, 1939.

Society, including particularly Dr. Hickey, and because of the great personal friendship with which Dr. Caldwell had honored me, I decided to put on a formal lecture termed the "Caldwell Lecture" which I trusted would turn out so well the Society would perpetuate it by making it an annual event. For the first Caldwell Lecturer I selected Walter C. Alvarez, then of San Francisco, now of the Mayo Clinic, who talked on "Peristalsis in Health and Disease." This lecture was published in our JOURNAL and later in book form, and still later revised as an excellent introduction to gastroenterology. The lecture was a great success and the Society voted to make it a permanent item of future programs.

Subsequent lecturers, like Alvarez, have maintained high standards, the occasion being made the most dignified and serious hour of our annual meeting, a matter of considerable personal gratification to its originator who in instituting the Caldwell Lecture builded better than he realized.

Although pancreatic disease has not attracted very much attention from roentgenologists, when compared with the study given more promising fields of investigation, yet a review of the literature reveals a measure of progress which it seems to me warrants careful evaluation of our present knowledge and the diagnostic and therapeutic possibilities afforded under careful use of the roentgen method. In some of these advances it has been my privilege to have participated. I therefore beg your indulgence while I endeavor to present the subject in an orderly manner, my own contributions falling into their natural places in the narration.

Aside from the findings in cases of acute pancreatitis and in pancreolithiasis, the present status of the diagnosis of pancreatic disease leaves much to be desired from the clinical viewpoint. Much progress has been made in devising functional tests of pancreatic efficiency, especially by American investigators, yet a positive diagnosis has remained very difficult. We are told that in the majority of cases of pancreatic pathology, either organic or functional, the lesion is not recognized. Pancreatic cyst, pancreatic carcinoma and acute pancreatitis are sometimes correctly diagnosed; but failure to diagnose is seen in a high percentage of the much more common cases of mildly subacute and chronic pancreatitis. In addition, there must be a considerable number of functional disturbances of the pancreas characterized by vague upper abdominal symptoms, sometimes only with gas distention and a feeling of discomfort, perhaps often with true pain, which should be attributed to pancreatic disease, occurring perhaps in the later years of life when there is greater chance for infection and vascular and connective tissue sclerosis. This supposition is supported by the considerable number of operations for other causes where the surgeon finds in the opened abdomen a pancreatitis previously unsuspected, a hardening or enlargement of the pancreas or evidence of fat necrosis from some previous unrecognized pancreatic lesion of acute or subacute character. It is therefore obvious that any method designed to arouse and confirm the suspicion of disease of the pancreas deserves general interest.

Many tests have been submitted in the effort to prove functional deficiency of the pancreas; pancreatic insufficiency has been one of the most widely discussed topics in papers on gastroenterology published in the last two years. The pediatric literature has furnished most convincing evidence of the association of steatorrhea and pancreatic disease. Harper has reported 8 cases all studied completely with analyses of the fat excreted in the intestinal dejecta; in 4 cases in which autopsy was secured atrophy of the pancreas was found. But, just as with the liver, there is such a wide margin of safety in the physiological reserve that even extensive pancreatic disease may be present with astonishingly little clinical and laboratory evidence. Various investigators place at seven-eighths to nine-tenths the amount of pancreatic tissue which must

suffer destruction before the efficiency of this organ is destroyed,—an explanation of the fact that many of the functional tests are strikingly positive only when the disease is well advanced.

The last decade was particularly fruitful in bringing about a better understanding of acute pancreatitis and a better appreciation of the rôle of the pancreas in fat metabolism, especially as it affects the liver. An example of one diagnostic advance in this field is the work of T. R. Brown in establishing the urinary normal of diastase and its great increase, sometimes as much as twenty times, in cases of pancreatic stone. But none of these tests is absolutely diagnostic because of confusion of the picture by an ever-present number of variables—as Brown says, differences in the motor and absorptive powers of the intestine and the possibility of vicarious enzymes from other sources, perhaps even of bacterial origin. Haring points out the importance of a thorough history and an exact analysis of the type of pain and malaise, which often have more meaning than the quantitative evaluation of all possible ferments.

Garrod said that the chief difficulty in diagnosing disease of the pancreas lies in not thinking of the pancreas. Körte remarked that the diagnosis of pancreatic disease would not be so difficult if only the physician would bear in mind that the patient has a pancreas. Therefore it is worthy of careful attention and consideration to review the symptomatology of pancreatic disease and to consider in what way the roentgenological method may contribute in arousing or confirming or denying the suspicion of such pancreatic affection.

BASIS FOR ROENTGEN STUDY

Three important clinical findings should at once attract attention to the pancreas—epigastric tumor, solar plexus pain and retention jaundice; but aside from these three, most of the symptoms of pancreatic disease are vague and indecisive. On first thought it would not seem that the roentgen method was likely to be of much use in any disorder not yet accompanied by alteration in the size, form and opacity of the pancreas; yet a number of indirect signs have been found constantly by many investigators. The so-called "duodenal motility" may suggest pancreatic disease, but, like pyloric spasm, it may be found with various lesions, and hence is not a decisive finding. But in organic pancreatic change, there are certain roentgen findings worthy of our consideration.

Direct roentgenologic depiction of the pancreas was not thought possible until the introduction of artificial pneumoperitoneum, in which several of our fellow members, especially Stewart, Orndoff, and Sante had such a prominent part. Hessel in 1921, before the Twelfth German Röntgen Congress, reported the demonstration of the pancreas by this method. However, pneumoperitoneum is a procedure which cannot be employed routinely without some risk and considerable annoyance, as was stressed by me in 1921, and cannot be resorted to as a matter of routine and without due consideration. As a diagnostic means it has come to be a method of exceptional rather than routine employment, even by those who first advanced its use. When about fifteen years ago I inquired of Carelli, of Buenos Aires, who at that time had studied more than two thousand personal cases of pneumoperitoneum, what use he would have for the method if he was not constantly confronted with the possibility of encountering hydatid disease so common in the Argentine, his reply was, "Practically never." In cases of suspected pancreatic cyst it is certainly proper to employ diagnostic pneumoperitoneum, but after all an exploratory operation is attended by only slightly more danger, and is far more informing; furthermore, it would permit the surgeon to proceed at once with whatever measure of relief or cure the findings would indicate.

The specific density of the pancreas is only slightly different from that of the surrounding tissues and, as yet, in roentgenology there has not been brought forward for

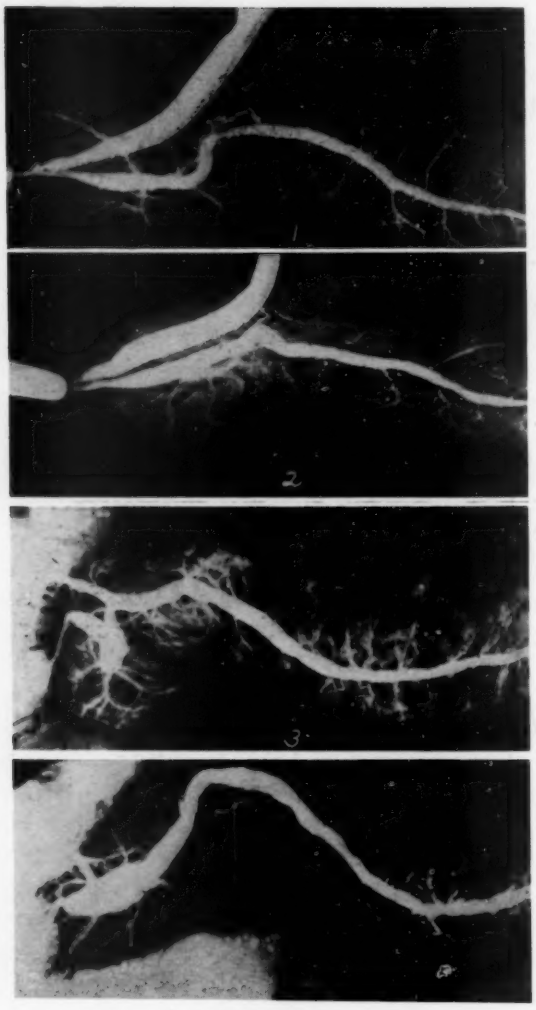


Fig. 1. Opaque injection of the pancreatic and biliary ducts of anatomical specimens illustrating the following principal variations: *1*, the choledochus and duct of Wirsung have a common opening into the intestine. *2*, the ducts are parallel with separate openings into the duodenum. *3*, the duct of Santorini is the principal excretory passage. *4*, ampullar dilatation of the duct of Wirsung; there are numerous other variations. (Schmieden and Sebening.)

use in pancreatic studies any suitable contrast material comparable to that which has made possible visualization of the liver and spleen, although such a method of visualization is within the range of possibility. Retrograde filling with a catheter through the papilla of Vater has been accomplished through duodenoscopy with a duodenoscope but the method is still extremely limited in possible use and entirely experimental.

Practically, the demonstration of the pancreas will nearly always be attempted by indirect means, and fortunately these are possible because of the close proximity of pancreas to different parts of the alimentary canal. Practically the only pancreatic lesions susceptible of direct and positive roentgenologic demonstration are pancreatic lithiasis and gas abscess of the pancreas. A cyst of the pancreas with such a degree of calcareous deposit in its walls that it was visualized has been recorded; but even then it was practically impossible to differentiate from pancreatic stone.

ANATOMICAL CONSIDERATIONS

Before proceeding further with our study a consideration of the anatomy of the pancreas willl be in order. The head of the pancreas is surrounded on three sides by the duodenal ring and partly by the prepyloric portion of the stomach. The connection between the gland and the upper and middle duodenum is a very firm one. While the duodenum encloses about a fourth of the circumference of the upper and middle thirds of the head of the pancreas, its lower border becomes narrower and sharper and often touches only the upper edge of the third part of the duodenum. The anterior surface of the head of the pancreas may be covered by the pyloric end of the stomach and the duodenum and by a part of the liver and the transverse colon. The neck of the pancreas lies to the left of the head. At the upper border of the neck there is a process of glandular substance, the tuber omentale, which generally projects above the lesser curvature of the stomach. The anterior surface of the neck shows an impression from the posterior wall of the stomach. The body of the pancreas follows to the left of the neck. Its anterior surface is turned towards the bursa omentalis, by which the pancreas is separated from the posterior wall of the middle portion of the stomach. The lower surface is covered by the transverse mesocolon. The tail of the pancreas is

adherent to the under surface of the spleen.

Recent observations tend to show that the pancreatic and common ducts in a rather large percentage of cases have a common channel, contrary to older ideas. Schmieden's work (Fig. 1) is especially illuminating and was a foretaste of the possible value of clinical cholangiography. Mehnen, after dissecting at autopsy 449 specimens, recorded that the two ducts joined above a common sphincter in 61 per cent of cases, thus permitting reflux of bile or pancreatic juice. Of the 275 cases with a common ampulla, 35 per cent had stones in the gallbladder.

Of greater clinical interest are the observations in living patients in whom the pancreatic duct has been visualized after injection of opaque oil into the common duct through a T-tube (Fig. 2), or into the duct during biliary operations. Hultén, Bottin, Hunt, Hicken and Best, Colp and Doubilet, and Leven have done much of this work. Leven found visualization of the pancreatic duct in 23 per cent of 91 patients who had 203 cholangiograms. Colp and Doubilet found amylase in significant amounts in the bile in nearly a third of all cases, evidence of the frequency of reflux of pancreatic juice into the common duct.

Hultén, of Sweden, for cholangiography during operations used a water-soluble radiopaque substance injected into the cystic duct. In 10 per cent of his cases the pancreatic duct was visualized.

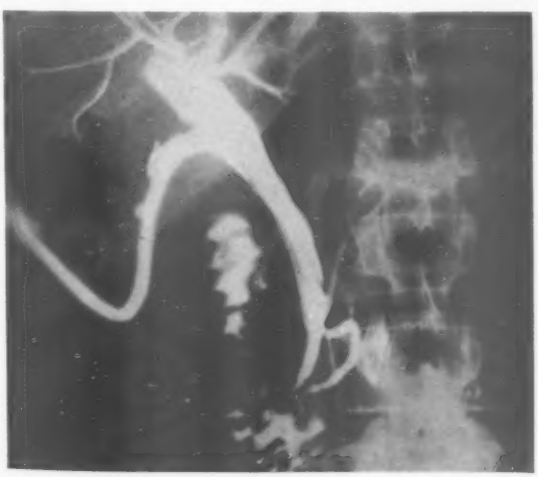


Fig. 2. Common opening of pancreatic and biliary ducts. Injection through biliary fistula.

Fig. 3. Lateral roentgenogram in the erect position after barium meal showing the thickness of the pancreas by the anterior displacement of the stomach.

The thickness of the pancreas is best measured in the first oblique diameter or in the straight lateral projection (Fig. 3). Slight but distinct variations in size occur physiologically with activity of the gland; it is a little larger after meals.

PANCREATIC CYSTS

As the most dramatic and the most frequently correctly diagnosed lesion of the pancreas, cysts may claim our first attention. Judd found that 88 cases were operated on for cyst of the pancreas out of 723,397 patients admitted to the Mayo Clinic. The cysts are smooth, hemispherical, tense, more or less fixed, located between ensiform and umbilicus, in the midline or slightly to the left in the majority of instances (Fig. 4). Of 168 cases only 18 were found below the umbilicus. Usually there is a zone of resonance between the

cyst and the liver and spleen. Displacement of the gallbladder takes place in large cysts and the duodenum is usually pushed upward and arched around the cyst. The subjective symptom—in one case for two years. The pain is continuous, has no relation to food but may be relieved by a bent or huddled-sitting posture. Nausea and vomiting are

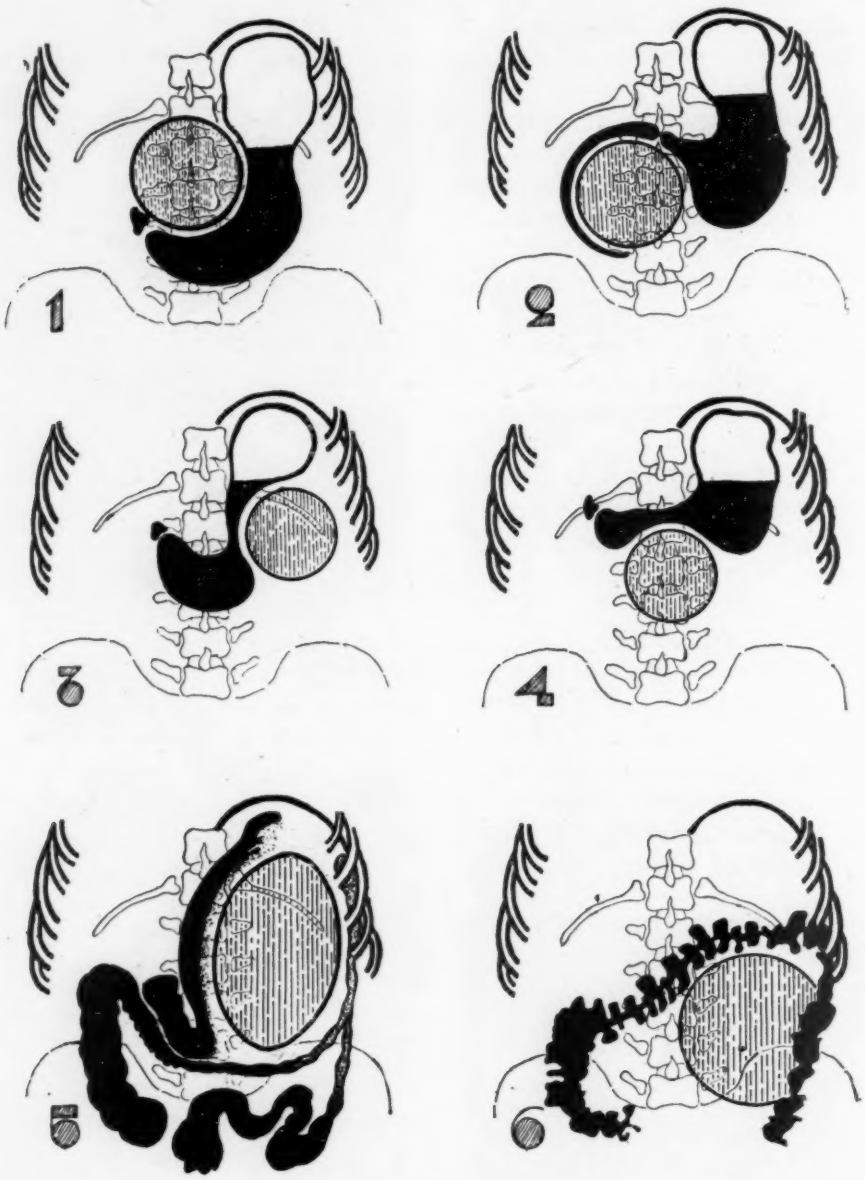


Fig. 4. Drawings from Porta and Roversi illustrating various roentgenological aspects of pancreatic cyst: *1*, gastrohepatic type; *2*, cyst of head of pancreas; *3*, cyst of tail of pancreas; *4*, cyst of body of pancreas; *5*, gastrocolic type; *6*, mesocolic type.

symptoms include pain or fullness in the upper abdomen, the pain being of sudden onset or slow development; dull sometimes and in other cases acute. Radiation through the back is common. Pain is often the only rare, and jaundice is seen in about 10 per cent of cases. There was a palpable tumor in 114 out of Körte's 121 cases. Mobility of the cysts suggests origin in the tail of the pancreas. There is a history of injury in 20

per cent of the cases, with an interval of three days to six years between injury and onset of complaints. The latent period between injury and symptoms is difficult to explain. Fluctuation in the size of the cyst is frequent. It may entirely disappear. Loss of weight and weakness are common. A rapidly growing tumor in the epigastrium strongly suggests pancreatic cyst, but must be differentiated from hydrops of the gallbladder, adrenal cyst, ovarian, mesenteric or omental cyst, hepatic cyst, hydronephrotic or cystic kidney, retroperitoneal tumors, tumor of the posterior gastric wall, aneurysm, splenic tumor, and perhaps other lesions. Diabetes is present in a relatively small percentage of cases. Echinococcus cysts may be encountered; they usually show marked calcareous degeneration.

Of all changes in the pancreas those are most adapted for roentgen demonstration which considerably alter its normal contours, such as solid and cystic tumors. The more hidden the cyst, particularly when it lies high up in the subphrenic region where it is not accessible to palpation and percussion, the more striking and valuable will be the roentgen appearance. Wolff published

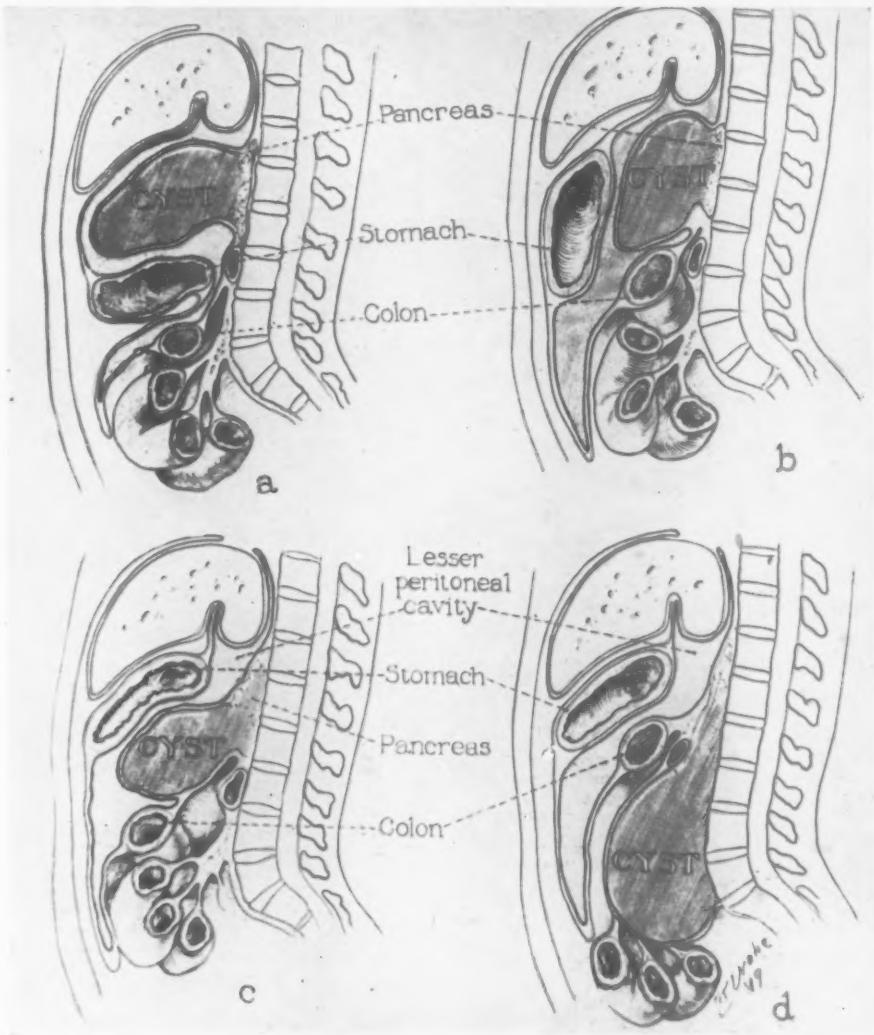


Fig. 5. Sketch modified from Guleke by Judd, Mattson and Mahorner showing the relation of pancreatic cyst to the abdominal viscera.

Fig. 6. Pancreatic cyst, gastrohepatic type.

the roentgenogram of a pancreatic cyst whose wall was the seat of such extensive calcium deposits that the tumor was demonstrable on direct roengen examination. This was a most unusual case, for so often we must depend upon indirect findings.

Judd, Mattson and Mahorner have published a series of excellent topographical sketches, modified from Guleke, showing very clearly the dislocations and compressions of the abdominal viscera which may result from the growth of a sizable pancreatic cyst. The sketches which are reproduced herewith (Fig. 5) are self-explanatory, and need no further elucidation. It is evident that, according to their origin, pancreatic cysts, when of sufficient size, may displace the stomach and colon downward; the stomach upward and the colon and small intestine downward; the stomach upward and the small intestine downward, while at the same time compressing the transverse colon which is held in a fixed position across the anterior aspect of the cyst; or the stomach and colon upward, while compressing or displacing the small intestine downward.

Tumors of the head of the pancreas may spread out the curve of the duodenum, as was long ago suggested by Crane. Hence a cyst originating in the head of the pancreas may displace and spread out the duodenum upward and toward the right, while causing a filling defect in the pars pylorica or in the lesser curvature of the stomach; whereas a cyst originating in the tail of the pancreas is more likely to distort the greater curvature of the stomach and the left half of the colon (Fig. 4). It is important in the preoperative study of a suspected pancreatic cyst to make this distinction, if possible; for cysts of the head should be approached by the abdominal route, while cysts of the tail are best dealt with through a lumbar incision.

A fairly certain sign of a cystic tumor displacing the stomach is a smooth contour of the defective shadow of the lesser curvature of the displaced stomach (Figs. 6, 7 and 8), the concavity being toward the suspected tumor and the edges of the gastric shadow indistinct, plainly suggesting a pressure from without rather than an intrinsic tumor. A tumor extrinsic to the stomach is indicated by the fact that it can be pushed away from the stomach shadow by palpation or similar manipulation under roentgenoscopic control. This is accomplished most easily with cysts. One must not deceive himself in doing these manipulations under the screen. Distinct peristalsis running over the suspicious filling defect in the lesser curvature speaks for an extrinsic lesion. Striking change in the form of the defect when the patient changes position is suggestive. Tumor outside of the stomach is most likely when there is an extensive palpable tumor. Adhesions between the retroperitoneal mass and the stomach are very misleading and difficult to differentiate.

The position of the cyst and its relation to neighboring organs can best be determined by palpation and percussion after distention of the stomach and bowel by air, and better still by roentgen examination in different directions after visualization of the stomach and colon by air or by the opaque meal. V. Redwitz found in his case

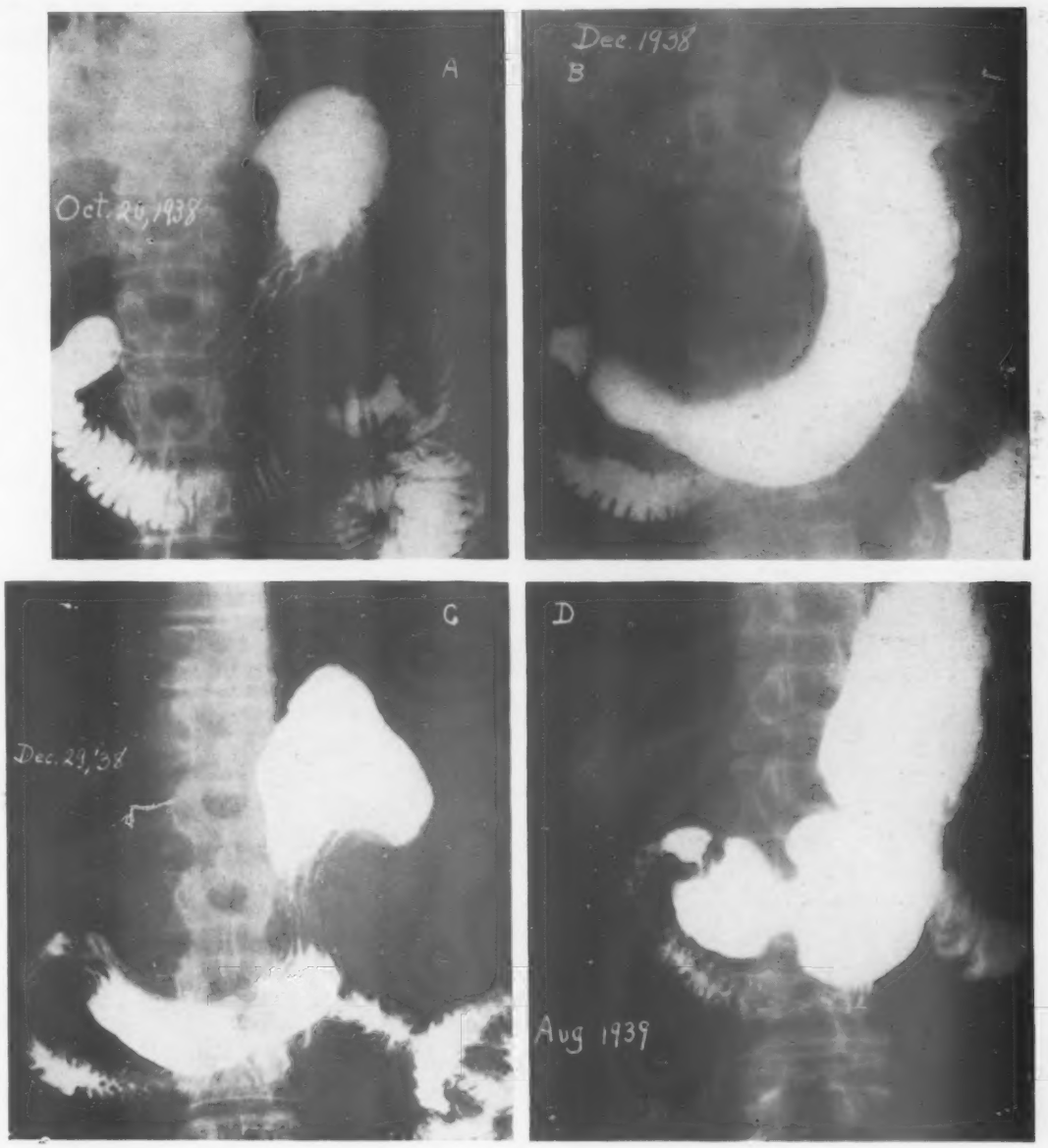


Fig. 7. Pancreatic cyst subsiding spontaneously. *A*, October 20, 1938; *B* and *C*, two months later; *D*, ten months later, the signs of tumor having completely disappeared.

that the cyst lay in front of the stomach and transverse colon, against the abdominal wall. Roentgenoscopy in different directions may show the relation of the tumor to the stomach and the transverse colon. Peristaltic waves may pass over the defect.

Schlesinger in 1912 made the first definite diagnosis of cyst of the pancreas on the basis of the stomach being pushed to the left by a dark shadow which could be differentiated from the other organs and around which the opaque meal collected in the form of a segment of a circle. In February, 1914, when the Chicago Surgical Society was entertaining a German delegation to the International Surgical Society which had just met in New York, the writer, then radiologist to St. Luke's Hospital, demonstrated the roentgen differentiation between a pancreatic cyst and an enlarged gallbladder in a patient of the late A. E. Halstead. The duodenum was pushed over to the right and

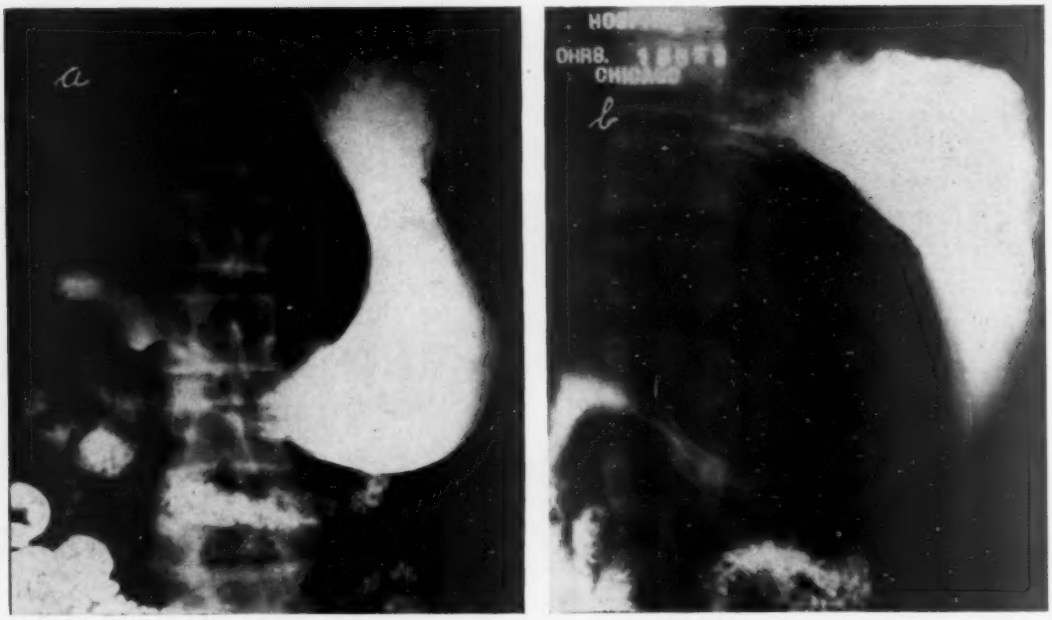


Fig. 8. Cyst of the pancreas, gastrohepatic type.

upward, compressed against the liver in a manner hardly possible with anything else than a cystic tumor coinciding with the head of the pancreas. Halstead's operation confirmed the diagnosis of pancreatic cyst. In this case, I combined roentgenoscopy with palpation under the screen, a very valuable refinement of roentgenoscopy which had just been popularized by Holzknecht. Such visualized palpation permits an appreciation of fluctuation, mobility of parts, and coincidence of sensitive points with visualized organs.

Fig. 9. Large spread of the duodenal curve in a normal individual tending to obesity.

In considering the rounding out or spreading out of the duodenal curve as a sign of enlargement of the head of the pancreas, it must be recalled that not only is the duodenum spread out but the pyloric end of the stomach may be distorted by pressure on the greater curvature side near the pylorus. The direction of the gastric or bulbar displacement is not always to be taken into account. The location of the mass above the horizontal portion of the doudenum is often sufficient to afford a clue as to the correct diagnosis.

Sometimes difficulty is encountered in trying to decide when the degree of spread of the duodenal loop really signifies the presence of a slight enlargement of the head of the pancreas. Obese individuals normally show a rather strikingly large duodenal curve (Fig. 9) as do other individuals who are not obese but who are tall and proportionately well built. We have observed this

large rounded curve of the duodenum in a patient with relaxation of the diaphragm and an abnormally high position of the stomach, and in the presence of ascites. It is important to consider the bodily type of the patient and the position of the stomach and colon.

Bird found that expansion of the duodenal loop may be caused by other tumors than cysts of the head of the pancreas (Figs. 10 and 11). He mentions such a duodenal distortion in cases of lymphosarcoma, metastatic carcinoma in lymph nodes, and carcinoma of the head of the pancreas. Unusual cases of abdominal Hodgkin's disease (Fig. 10*c*) may also simulate pancreatic tumors.

If the tumor is in the tail of the pancreas the greater curvature shows a filling defect when the patient lies down which disappears when he stands up. Displacement of the duodenojejunal angle and compression of the third part of the duodenum with stasis is more marked with lesions of the tail of the pancreas. The most characteristic sign is displacement of the greater curvature of the stomach upward and to the right and downward displacement of

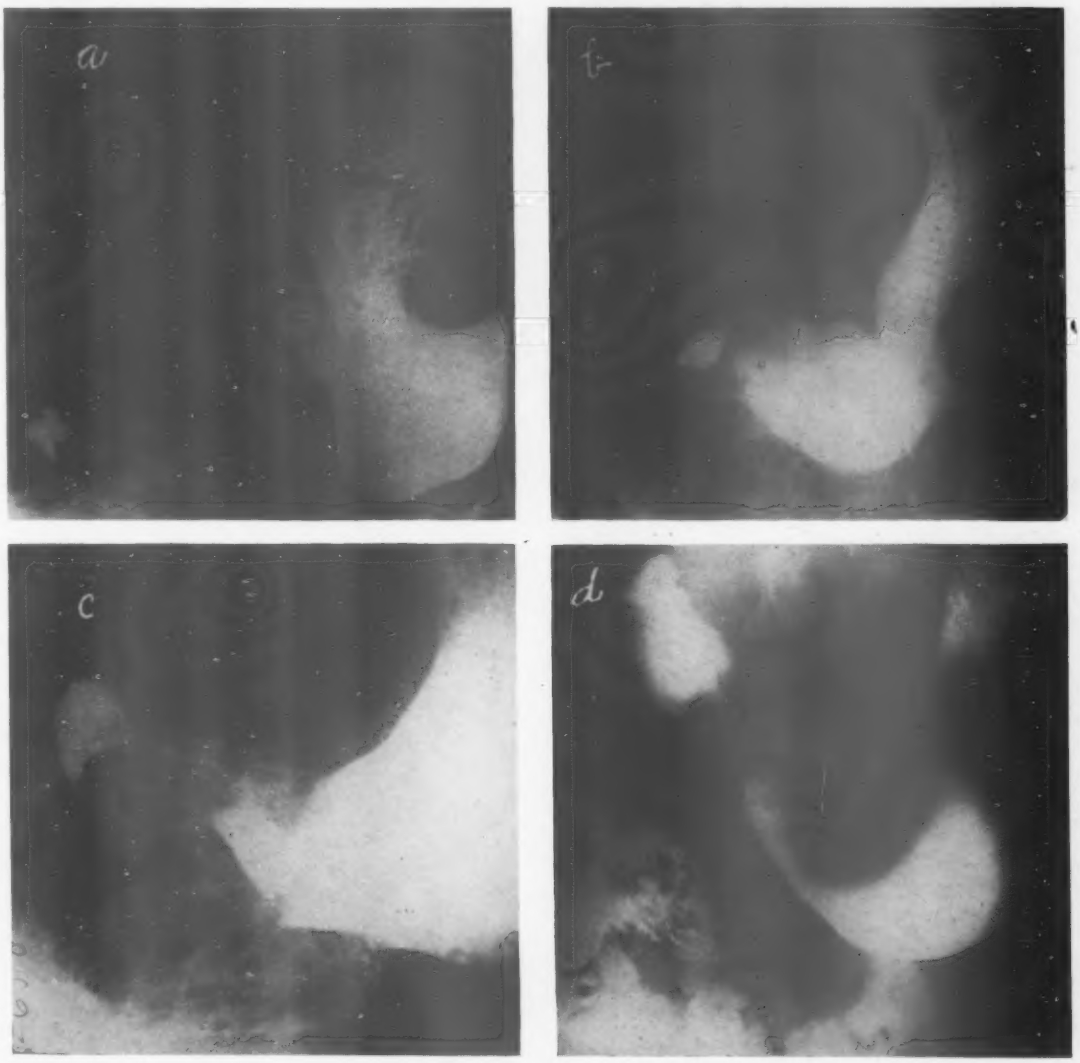


Fig. 10. Four cases of gastric deformity from without: *a*, splenic indentation in greater curvature; *b*, carcinoma of the greater curvature; *c*, Hodgkin's disease of the stomach; *d*, retroperitoneal sarcoma.

Fig. 11. Cyst of the lesser peritoneal cavity simulating pancreatic cyst.

the duodenojejunal flexure; also compression of the first loop of the jejunum, with resulting insufficient visualization. When the tumors are large there is also compression of the proximal loop of the splenic flexure of the colon.

Observation of diaphragm excursion should show diminution on the side where the cyst is located; elevation of the diaphragm is sometimes noted.

Differentiation between pancreatic cysts and cysts of neighboring organs is difficult because of their close proximity—kidney, suprarenals, spleen, liver, all preferred sites for cysts, peritoneal and retroperitoneal, parasitic and non-parasitic. It is easier to decide whether the tumor is solid or cystic, but the differentiation from cysts or neighboring organs must be worked out by cholecystography, urography, salpingography, etc.

Occasionally a pancreatic cyst has been identified by artificial pneumoperitoneum. Surely, if any indication exists for the use of diagnostic pneumoperitoneum, it is a case of suspected abdominal cyst, although many would prefer an exploratory operation. Buckstein, in a tumor of the head of the pancreas, passed into the duodenum a sound with a metal tip and many holes in the portion next to the tip, and then injected barium through the sound, demonstrating the unusually large curve of the duodenum around the tumor.

Ureteral catheterization may fail to distinguish a pancreatic cyst from a renal tumor; in one such personal instance the cyst lay in the right hypochondrium and compressed the ureter so that in half an hour no urine came from the right kidney.

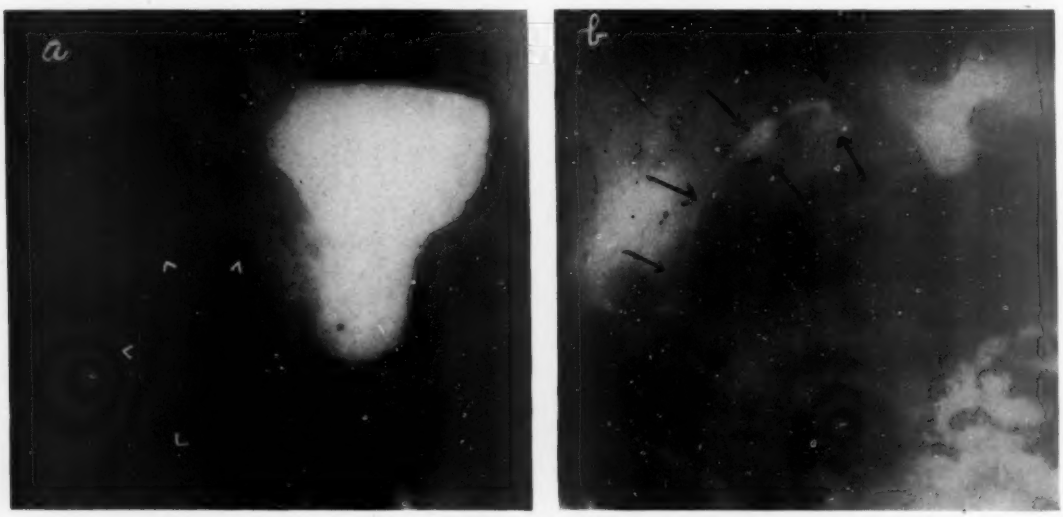


Fig. 12. Writer's first case of pancreatic cyst, 1914. Duodenal spread.

It is difficult to conceive how one could mistake an ovarian for a pancreatic cyst, but such confusion is reported. Mesenteric cysts are, as a rule, very movable. Diagnostic puncture of a suspected cyst through the unopened abdominal wall, as well as therapeutic puncture in the opened abdomen, is usually now only of historical interest. Tumors of the gallbladder rarely attain the size of pancreatic cysts, and they may be differentiated as above suggested in my case operated on by Halstead: a gallbladder tumor will push the duodenum away from the liver, toward the left and downward; whereas a pancreatic tumor spreads the duodenal curve, making it larger than usual (Fig. 12). Gallbladder cysts move with respiration; pancreatic cysts may fluctuate, and this fluctuation may simulate movement up and down with respiration.

It has now become almost routine to carry out a roentgen study of the alimentary tract in differentiating any palpable tumor which is not definitely identified as lying outside of the digestive tube, perhaps in the genitourinary organs, or some retroperitoneal tumor. Even when it seems clearly not a lesion of the digestive tube, the roentgen visualization and study of the alimentary tract as a whole may throw important light on the identity of the tumor in question. Wiese and Larimore found in a series of 126 cases of extra-alimentary abdominal tumors that out of 21 extra-alimentary tumors found in the epigastrium or upper abdomen 18 were of pancreatic origin. Three were retroperitoneal and independent of the pancreas. Of the 18 pancreatic tumors, 8 were cysts and 10 primary carcinomas. Fourteen of the 18 were recognized. There were 7 cases of tumor of the upper central abdomen which did not influence the circle of the duodenum; none of these were of the pancreas.

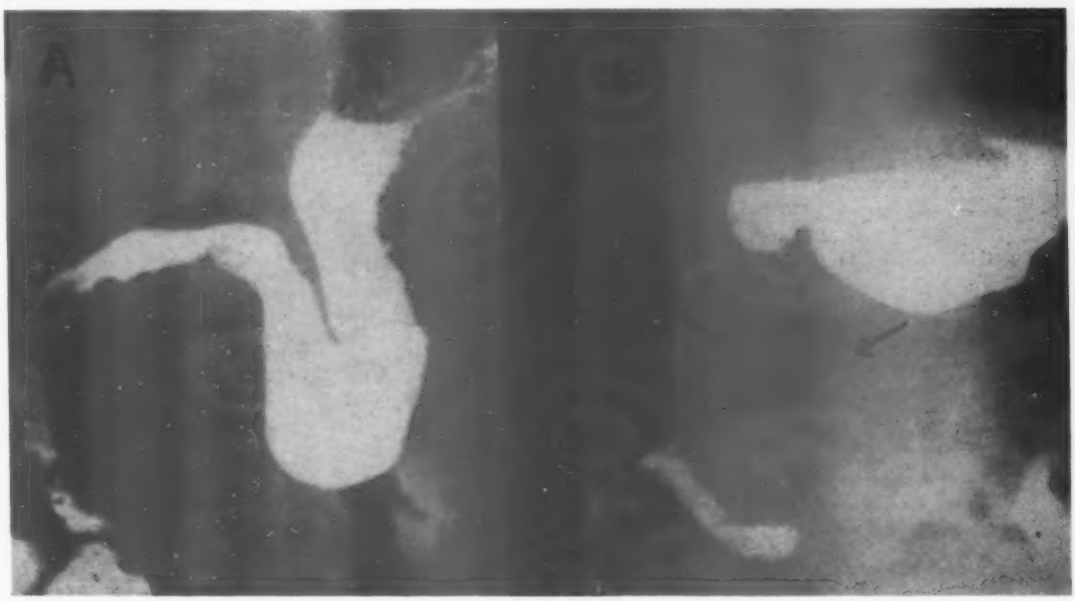


Fig. 13. Pancreatic gas abscess (Kuhn).

GAS ABSCESS OF THE PANCREAS

Assmann, Bittorf, Haenisch, and others, have reported the roentgenological recognition of this condition. The first thing observed is an accumulation of gas in the mid-epigastric region, especially when the patient is studied in the erect position, or lying on the side. One sees a fluid level, representing the level of purulent material, with the gas overlying it (Fig. 13). The col-

Fig. 14. Lateral film according to the technique of Engel and Lysholm in case of carcinoma of the pancreas.

lection of fluid is not connected with the stomach. The appearance is very similar to that presented by a diverticulum of the small bowel, examined in the erect position; and, conversely, when small, such a pancreatic abscess cavity may simulate a diverticulum. However, when it is large, the gas collection may extend upwards as high as the left diaphragm and simulate a subphrenic abscess. A similar condition has been noted by Hörhammer in a suppurated cyst of the pancreas. Other local accumulations of fluid, with air or gas above, of different etiology in this region might cause confusion, such as tuberculous peritonitis, multiple adhesions from old peritonitis or intestinal cysts.

CARCINOMA OF THE PANCREAS

Gillespie in a series of 1,861 autopsies found 43 pancreatic tumors which constituted 10 per cent of all the carcinomas of the series. The tumor involved the head of the pancreas in 32, the body in 5, and the tail in 6 cases. Jaundice was present in half of the caput lesions. Three-fourths of the cases had developed metastases. Clute says 3 per cent of all cancer deaths arise from cancer of the pancreas and total four thousand a year in the United States. Hick and Mortimer in 7,932 autopsies at the Cook County Hospital (Chicago) found only 50 instances of pancreatic cancer, or considerably less than 1 per cent. There were 942 cases of cancer, so they estimated that pancreatic carcinoma represents 5 per cent of all cancer cases. Carcinoma of the stomach was found four times more frequently. Of the 50 cases, 22 were of the head, in the tail 23, in the whole pancreas

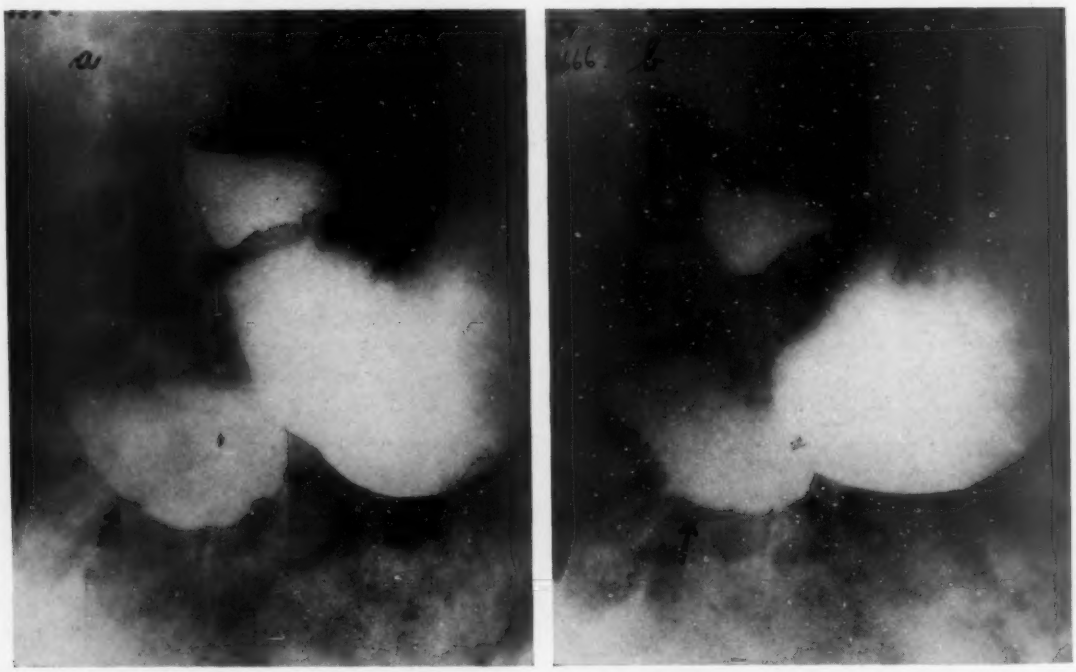


Fig. 15. High grade duodenal obstruction from adhesions and compression by pancreatic cyst.

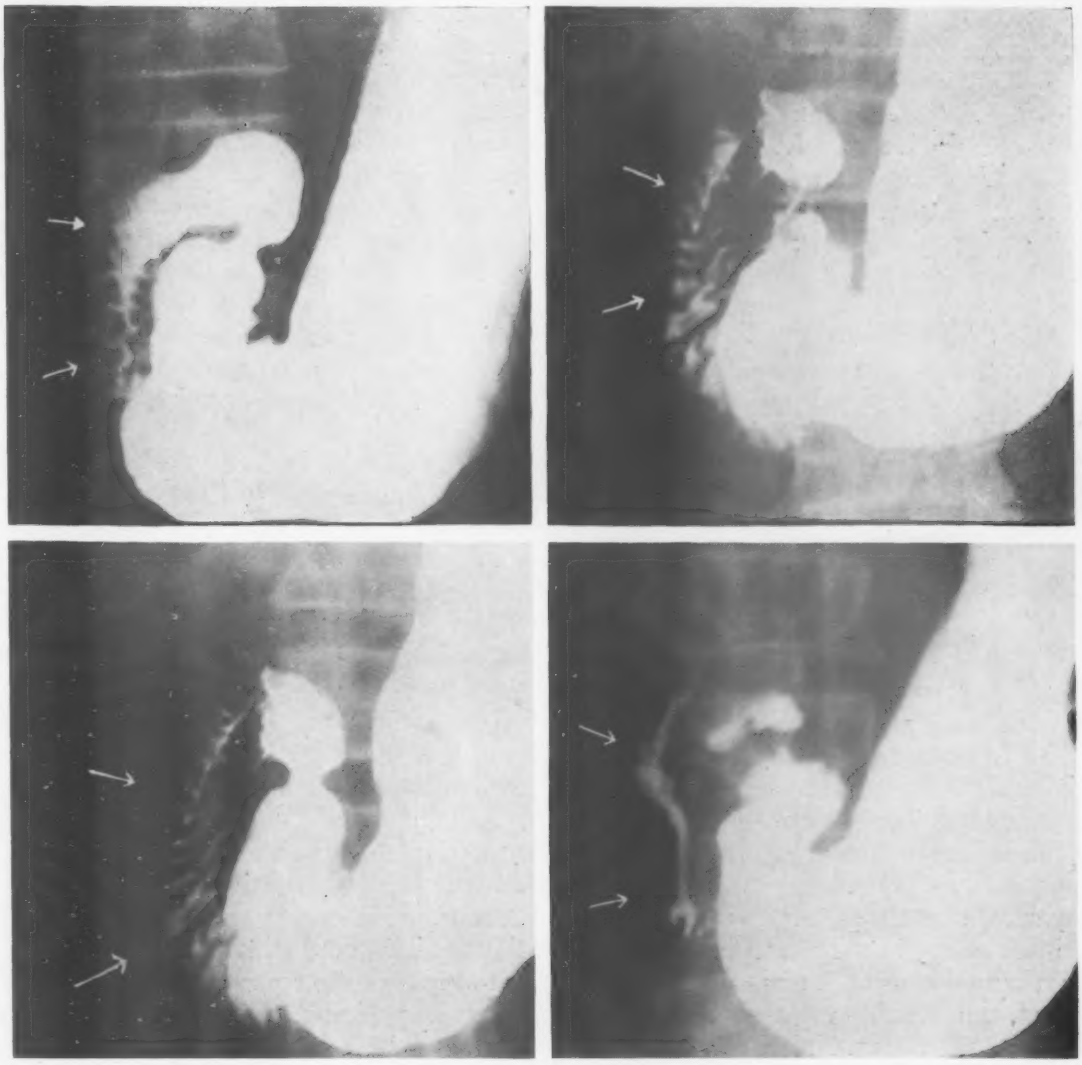


Fig. 16. Four films of the same case illustrating the varying pattern of the duodenum in hyperperistalsis with carcinoma of head of pancreas.

4, and in one there was also duodenal invasion.

The differential diagnosis of pancreatic tumors is difficult. Solid tumors bring about compressions and obstructions in the neighboring organs. Thus there is often pancreatic insufficiency and chronic biliary obstruction with icterus, even before the tumor can be palpated. When the tumor reaches a certain size it begins to displace the adjacent organs.

Carcinoma of the pancreas may give rise to a number of different manifestations susceptible of roentgen demonstration. Except for a peculiar type of duodenal motility which I have observed in a number of cases of pancreatic carcinoma (but observed also in some other conditions), it was until recently considered that the roentgenological diagnosis of early pancreatic cancer was very unsatisfactory and unreliable. There were no dependable roentgenological signs until malignant growth caused some appreciable enlargement of all or part of the gland. These changes depend somewhat on the part of the gland involved.

If there is no palpable tumor, there may be no direct roentgen sign. An ordinary dif-

Fig. 17. Irregular filling defect in duodenum by extension from carcinoma in head of pancreas.

fuse infiltrating carcinoma may not produce any change from the normal. Köhler calls attention to abnormal palpability of the stomach when the patient is examined in the erect position. Carefully observed palpation under roentgenoscopic control may show a pad sign, with abolition of the barium shadow in the stomach under much less than the usual amount of pressure needed, thus leading to suspicion of a mass behind the stomach. This is where the lateral film (Figs. 3 and 14) will prove of greatest value, by showing the displacement of the stomach from behind by the retroperitoneal mass.

The mucosal pattern may be altered if the duodenal wall is invaded, the degree of alteration varying from slight increase of the serration (the peri-vaterial deformity or inverted 3 sign of Frostberg, Fig. 19) to a high grade of obstruction (Fig. 15). If less than complete obstruction exists, there may be duodenal surge from the churning movements (Fig. 16), with an occasional spurt of opaque material through the stenosed duodenal segment. This may occur from edema involving the intestine at the duodenojejunal junction in connection with carcinoma of the body of the pancreas, without any actual extension into the duodenum. Duodenal contour defects may be due to actual invasion by carcinoma from the pancreas (Figs. 17 and 18).

Altered physiological manifestations may be observed in the stomach and duodenum, such as slowing of gastric peristalsis and clearance or slow motility of the small intestine without evidence of actual obstructive lesions. These do not constitute definite evidence of pancreatic disease, but the finding should invite a careful study with reference to some organic lesion, such as a pancreatic cancer.

Defects of contour in the middle of the

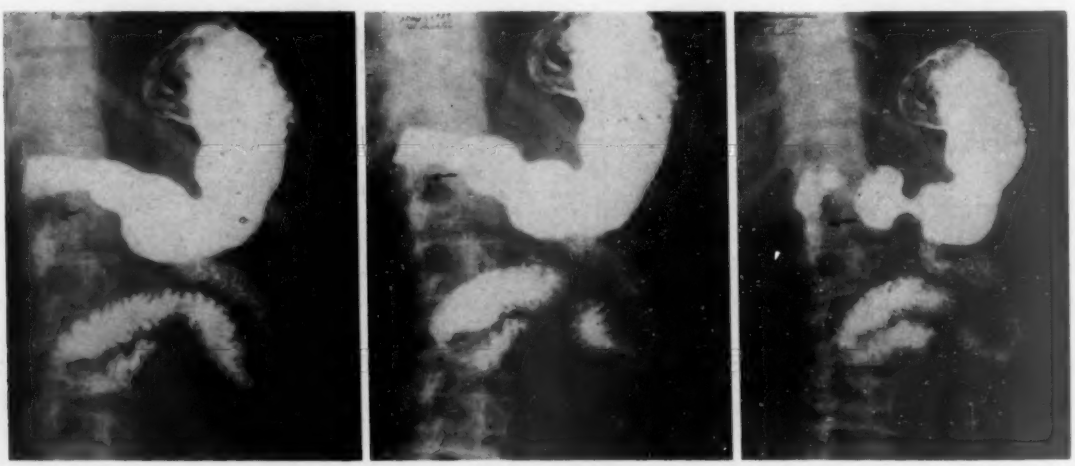


Fig. 18. Filling defect in duodenum, constant in type and location, with duodenal obstruction, in carcinoma of the pancreas.

stomach, and especially those seen in the region of the greater curvature, are likely to result from carcinoma of the body of the pancreas and especially the pancreatic tail. There may be a constant, irregular filling defect in the middle portion of the greater curvature, or the so-called "pad defect." Such a filling defect, though usually considered and reported as indicating carcinoma of the stomach itself (Fig. 10*b*), may betray a pancreatic tail carcinoma if special pains are taken in the roentgenoscopic palpation, having in mind the possibility of such a pancreatic lesion. When a carcinoma of the pancreas has extended to the posterior gastric wall, it will be difficult to say from the roentgen study alone whether it is primarily a gastric or a pancreatic lesion. Mucosal studies in the stomach should be decisive; also studies in the lateral position. When a pancreatic tumor grows upward into the lesser omentum and reaches a certain size, it pushes the middle part of the stomach over to the left. The result may be a sort of hour-glass formation indistinguishable from carcinomatous hour-glass stomach. Even when the filling defect due to the compression of the suspected tumor is smooth, it does not rule out carcinoma of the pancreas; but an infiltrating or scirrhous carcinoma of the stomach extending along the lesser curvature may also cause a rigid saddle-shaped indentation in the stomach with very smooth contours. The new technique devised by Engel and Lysholm is valuable.

The Engel and Lysholm technique involves distention of the stomach with air or gas *in the abdominal decubitus*, and examination of the patient with a tube placed at the side of the table, the rays passing parallel with the floor, the film being held vertically at the side of the patient. It may thus become possible to determine the size of the pancreas which in the normal state should equal approximately the diameter of one of the vertebral bodies. The technique affords a definitely valuable means of differential diagnosis between tumor of the stomach and a pancreatic tumor. Two films are made: one lateral, quickly followed by an anteroposterior exposure. The two films must be made very quickly after the patient has swallowed the effervescent powder. If too much carbon dioxide escapes into the small intestine it produces gas bubbles which interfere with proper estimation of the size of the pancreatic shadow. It is important always to use the same focal distance, 100 cm. for the lateral and 140 cm. for the anteroposterior roentgenogram being recommended. The pancreas is seen as a triangular shadow filling the angle between the body of the stomach and the pyloric canal, bounded behind by the spine. A vertical film is also made in which one usually fails to show the pancreas, but in case of a tumor of the cauda there is a change in form of the gas-distended stomach. The method constitutes a very definite advance in roentgenography of the pancreas.

Hershenson suggests a method which is less useful but to be considered. He says that if a patient with a pancreatic tumor is caused to stand with the abdomen facing the upright roentgenoscope, and then is observed roentgenoscopically while the table is tilted downwards to the horizontal, the defect due to the compression of the spine across the middle of the stomach will become visible much sooner, thus indicating the presence of a pancreatic mass. That the mass is really extragastric and not a lesion of the mucosa of the stomach itself is demonstrated by the presence of uninterrupted lines in the gastric mucosal pattern. At 20 degrees from the vertical the filling defect of the pancreatic tumor may be only slightly visible, at 45 degrees the stomach is more extensively compressed by the pancreatic tumor behind it. The filling defect disappears when the patient is further raised to the vertical position.

Frostberg's inverted figure 3 sign due to encroachment upon the duodenal shadow by peri-vaterial enlargement of the pancreas, is a valuable contribution to the early diagnosis of pancreatic lesions. Compression technique during a careful mucosal visualization of the duodenum may reveal very early changes in the mucosal configu-

ration of the second portion. Frostberg reported 3 cases with a filling defect resembling an inverted figure 3, representing pressure on the head of the pancreas (Fig. 19). There are two small depressions, smooth, well-defined with a small protrusion between. The neighboring duodenal folds are distorted and the corresponding mucosa shows signs of pressure interpreted as a slight enlargement of the head of the pancreas. I have had 2 cases and Feldman has recently reported 2 cases of similar character. The changes resembling an inverted figure 3 are not typical of any particular disease of the head of the pancreas, but may occur in cases of tumor and pancreatitis, possibly also in simple edema. The stopper-like protrusion to the left between the two small depressions would seem to be located in the region of the papilla of Vater.

Fig. 19. Frostberg's inverted figure 3 sign. The central arrow points to the insertion of the common duct into the duodenum, and above and below it the duodenal defect caused by the impression of the swollen pancreas.

In a case of suspected cancer of the pancreas, the findings may indicate a carcinoma of the papilla of Vater. I have successfully recognized one case of this type, but the illustration which is taken from Berg (Fig. 20) is more instructive than my own case (Fig. 21). Determination of the internal and external pancreatic secretions formerly were the mainstay in differentiation but the modern roentgen study of the duodenal relief with compression should permit that differentiation.

An important phase of the roentgen examination relates to whether the suspected tumor is extraventricular. The decision still remains as to whether it belongs to the pancreas or to some other extragastric organ. Here the results of visualized palpation under the fluoroscopic screen and meticulous mucosal studies may settle the question. When the tumor can be separated from the stomach by palpation or similar manipulation or when distinct peristaltic waves can be seen running over the suspicious place in the lesser curvature, or when there is a striking change in the form of the defect or even its disappearance on change of position, one may reasonably presume the tumor to be extraventricular. It may not be possible to distinguish between a carcinoma of the pancreas and a

Fig. 20. Small rounded filling defect in second part of the duodenum, due to early carcinoma of papilla of Vater (Berg).

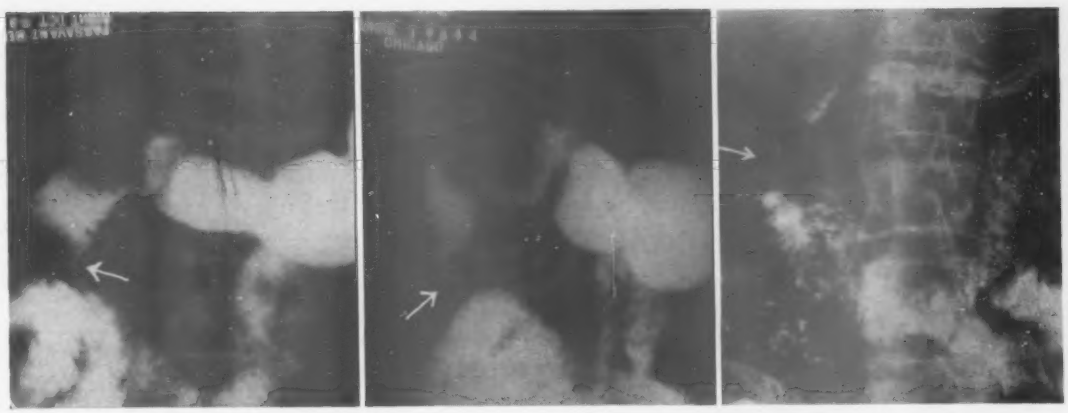


Fig. 21. Soft pedunculated carcinoma of duodenum originating in ampulla of Vater.

retroperitoneal sarcoma (Figs. 22 and 23).

The "pad sign" refers to a circumscribed filling defect in the gastric silhouette seen in the horizontal position, which nearly or completely disappears when the patient stands before the vertical roentgenoscope, but which is reproduced in the vertical position by having the patient press his abdomen hard against the screen, or by making slight pressure with the examining fingers. This sign may be present, however, in cases of carcinoma of the posterior gastric wall, and also with certain pedunculated tumors of the stomach.

Fig. 22. Retroperitoneal sarcoma.

The head of the pancreas is the part usually involved in carcinoma, hence one would expect to find changes in the duodenum reflecting this condition (Figs. 16, 17 and 18). The earliest phenomenon observable is a type of duodenal motility which is similar to that ascribed to me by Kreuzfuchs and other Viennese writers in

Fig. 23. Sarcoma in head of pancreas. Operative proof (Katsch).

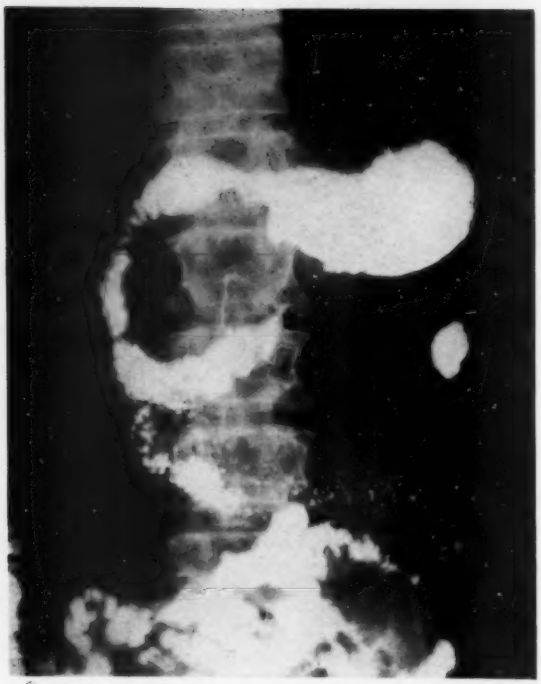


Fig. 24. Carcinoma of head of pancreas. Duodenal spread. Irregular contour of duodenal shadow.

1912, as having been observed in the early minutes of gastric clearance in duodenal non-stenosing ulcer. There is an outpouring of the opaque contents of the stomach at a startlingly rapid rate, such as one sees with achylia. In duodenal ulcer this rapid outpouring is soon brought under control, so that in many cases the final time of gastric clearance is prolonged beyond the normal, but in carcinoma of the stomach and early carcinoma of the pancreas the rapid emptying continues until the stomach is clear. In later stages obstructive phenomena are observed (Fig. 15).

With the appearance of enlargement of the head of the pancreas, we expect to find, and often do find, a spreading out, fan-wise, of the duodenal curve with increase of the distance between the filled descending part of the duodenum and the antrum pylori (Fig. 24). This is seen also with pancreatic cysts, but the contours are more or less irregular in cases of neoplasm. Paul emphasizes the fact that the classic picture of enlargement of the duodenal curve is frequently absent in carcinoma. In some cases the irregularity is such that one can state with assurance that the malignant growth in the pancreas has actually extended on to the duodenum, causing a filling defect, or multiple filling defects, with a ragged outline of the duodenum (Fig. 17), just as we find a ragged contour in many cases of gastric carcinoma. Carcinoma of the head of the pancreas can simulate carcinoma of the gastric pars pylorica. In a pancreatic tumor the contours may be indistinct, the whole part lacking in contrast, with an indistinctness to the boundary of the filling defect not quite like that seen in pyloric carcinoma.

If by retroperitoneal infiltration towards the duodenojejunal junction or by actual compression of the duodenum at any point, a pancreatic carcinoma causes hindrance, the result will be the typical appearance of duodenal stenosis. The site and degree of the constriction vary. In many cases there is seen a constant, complete cast of the duodenum; but this of itself is not characteristic of pancreatic carcinoma, since it may also result from gastric carcinoma (Fig. 25) or ulcer, the malignant or inflam-

Fig. 25. Duodenal obstruction from extension of gastric carcinoma into duodenojejunal flexure.

matory process having extended to the peritoneum covering the duodenum near its junction with the jejunum, causing secondary relative obstruction of the duodenum and secondary delay in the emptying time of the stomach.

The duodenal obstruction produced by carcinoma of the pancreas may be such as to produce extremely painful colicky attacks causing the patient to scream with agonizing sharp distress. One of our patients whose films are shown herewith (Fig. 16) was promptly relieved of these terrifying, sharp, cramping pains by a duodenojejunostomy.

There has been described also a carcinomatous paraduodenal ulceration in a malignant pancreatic tumor extending to the wall of the duodenum. Barium may fill the cavity of the ulcerated area, producing the appearance on the roentgenogram somewhat resembling a diverticulum (Herrnheiser). The differentiation of this sign from a diverticulum of the duodenum or the niche of an ulcer should not be difficult. The contours of the shadow of a diverticulum are smooth.

The duodenal bulb occasionally shows changes of a constant nature, not in keeping with a history of ulcer of the duodenum (Fig. 26); when this type of constant deformity of the first part of the duodenum is associated with some of the signs suggestive of carcinoma of the pancreas, the sign is very suggestive. This deformity may be due to the adhesions of a carcinoma of the head of the pancreas or to its actual growth into the duodenum. It is not often possible to diagnose carcinoma of the pancreas on the basis of the bulb deformity alone.

Ransom made a roentgen study by means of the barium meal, with or without examination of the colon by the opaque enema, in 93 of 109 cases of pancreatic carcinoma, all proved by operation or autopsy. While the examination was entirely negative in three-fourths of the cases, it is significant that in the remaining one-fourth the findings were such that a pancreatic tumor was definitely suspected and even a positive diagnosis ventured. The important findings were a widening of the duodenal normal curve, narrowing of the duodenal lumen or indentation of the shadow of the duodenum or stomach by pressure from without. In an indirect way the examination was also of value in excluding carcinoma of the stomach or of the colon, both of which lesions may be confused very easily with carcinoma of the pancreas, especially when jaundice is absent. Ransom says that the laboratory studies were of practically no value in the diagnosis of cancer of the pancreas, as shown in his series of 109 cases, verified by operation or necropsy, while the roentgen studies were positive or suggestive in one-fourth of the cases.

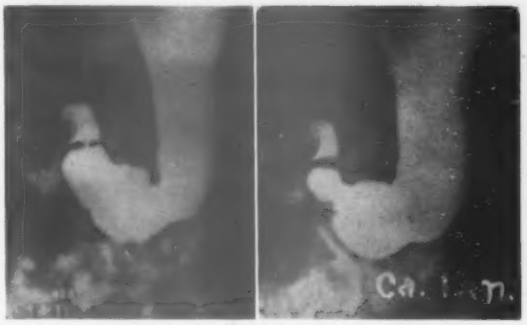


Fig. 26. Carcinoma of head of pancreas causing duodenal bulb defect hinting at duodenal ulcer.

PANCREATIC LITHIASIS

The stones which may develop in the excretory ducts of the pancreas are small, as a rule, perhaps the size of a pea or only like sand, but occasionally they attain to the size of a walnut. Shupman found one case in his collection from the literature where the stone was 5.0 cm. in length and 1.0 cm. in width. Martina found a stone weighing 2 ounces. They vary in shape and may be spherical, oval or irregularly formed, with either a smooth or a rough surface. Ruth reports a case where the stones were faceted and worn smooth by the action of the aorta. They are usually white, less often dark brown or black. Aschoff mentions the possibility that occasionally gallstones mi-

Fig. 27. Pancreatic stone lying within duodenal curve.

grate from the common duct into the pancreatic duct. When present, the stones are usually multiple, lying either in the main ducts or in the smaller radicles. In some cases the pancreas has been filled with stones, the substance of the gland having been to a large degree destroyed.

The canalicular calculus situated in the duct of Wirsung or its branches does not lead to any gross functional disturbance, any diabetic symptoms or a steatorrhea; it is amenable to surgical removal and drainage. In the cases of pancreatitis petrificans the calcium deposition in the pancreas is secondary and not surgically accessible. Diabetes and steatorrhea are more frequent. The stone in the excretory passages causes obstruction and sclerosis. With parenchymatous calcification the sclerosis is primary, inducing the pancreatitis petrificans. The stones may give rise to abscess or cyst formation. In one case the stone in the cyst proved to be a portion of the calcareous wall of the cyst which had broken off and had fallen into the cyst cavity. Stones may ulcerate through into the stomach or into the peritoneal cavity or into the duodenum causing severe hemorrhage. Rarely the stone may be found in the stools.

In most cases the calculi consist of carbonate or phosphate of lime, although the normal pancreatic secretion contains no calcium carbonate. Mayo-Robson in 1904 first called attention to the fact that pancreatic calculi contain 50 per cent or more of calcium carbonate, and that on this account they should be demonstrable roentgenologically.

In the roentgenogram pancreatic calculi show as solitary or multiple, round or irregular shadows lying in the neighborhood of the first and second, sometimes in the upper border of the third, lumbar vertebrae. In one of my cases the stone cast a rather smooth ovoid shadow, lying within the curve of the duodenum (Fig. 27), resembling a duodenal diverticulum situated near or coinciding with the ampulla of Vater, but careful check of the examination showed that the shadow existed before any opaque material had been administered. The multiple shadows should not be confusing, for they usually outline very prettily a train leading to the left and upward from

Fig. 28. Large group of pancreatic calculi in head of pancreas.

the head of the pancreas, in a line corresponding to the course of the pancreatic duct (Figs. 28 and 29). Solitary stones cast shadows lying nearer to the spinal column than one would be likely to find kidney or gallstones, though a concretion in a horseshoe kidney or an unusually placed gallbladder must be thought of. I have often found gallstone shadows lying in front of the spinal column, and occasionally even to the left of the spinal shadow.

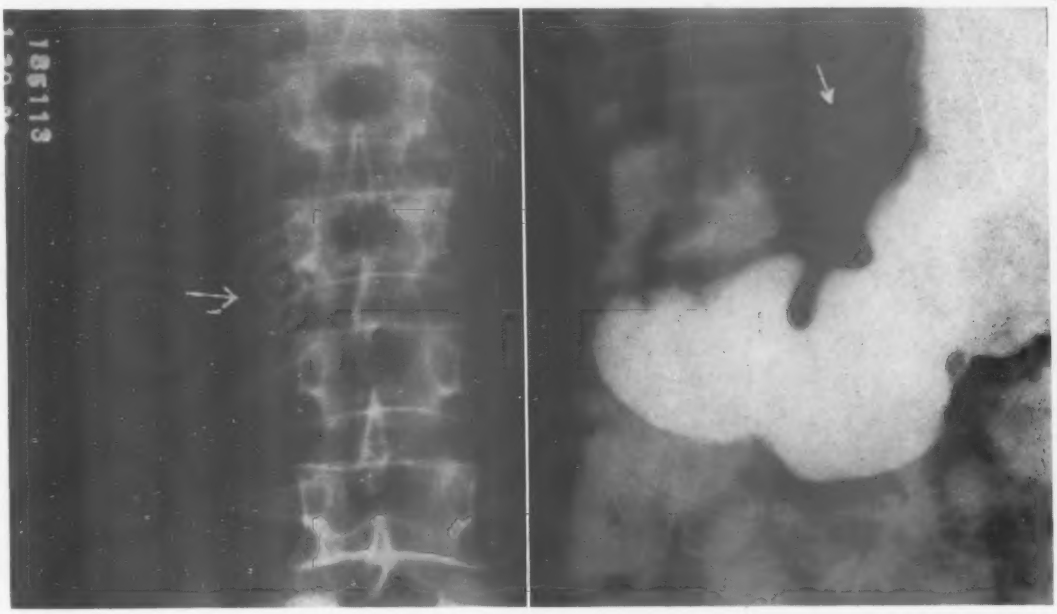


Fig. 29. Calculi in both head and tail of pancreas.

In differentiating, gallstones may now be identified with very great surety by the use of cholecystography, and stones or other calcifications in relation to the kidney should be detected by pyelography. One should also exclude mesenteric or retroperitoneal calcifications, such as calcareous glands, lime deposits in an aneurysm or in the wall of the atheromatous abdominal aorta; opaque residues in diverticula of the duodenum, jejunum, or transverse colon; phleboliths of the splenic vein, and perhaps other shadows. Calcified glands usually present a mulberry-like shadow characteristic of the condition; moreover, one is likely to find several similar shadows scattered throughout the abdominal area. They do not confine themselves to the area corresponding to the pancreas, and under proper manipulation may be assumed to be more or less movable. In excluding aortic wall calcareous deposits a lateral film of the abdomen, as for making a lateral roentgenogram of the spine, is usually decisive, demonstrating the suspected shadows as lying parallel to the spine and with their long axis disposed in the longitudinal rather than in the transverse direction. Calcification of the abdominal aorta may be thus discovered more frequently than most of us realize. Peutz cites the case of a woman of seventy-seven with advanced arteriosclerosis. The suspected shadow, instead of pancreatic calculi, proved to be due to advanced calcification in the wall of an abnormally tortuous splenic artery, which was covered on the anterior side by the pancreatic parenchyma. Opaque meal residues should not cause difficulty, though sometimes diverticula with small openings into the intestine retain barium for many days. The splenic vein, next to the pampiniform plexus, is the most common site of venous calculi.

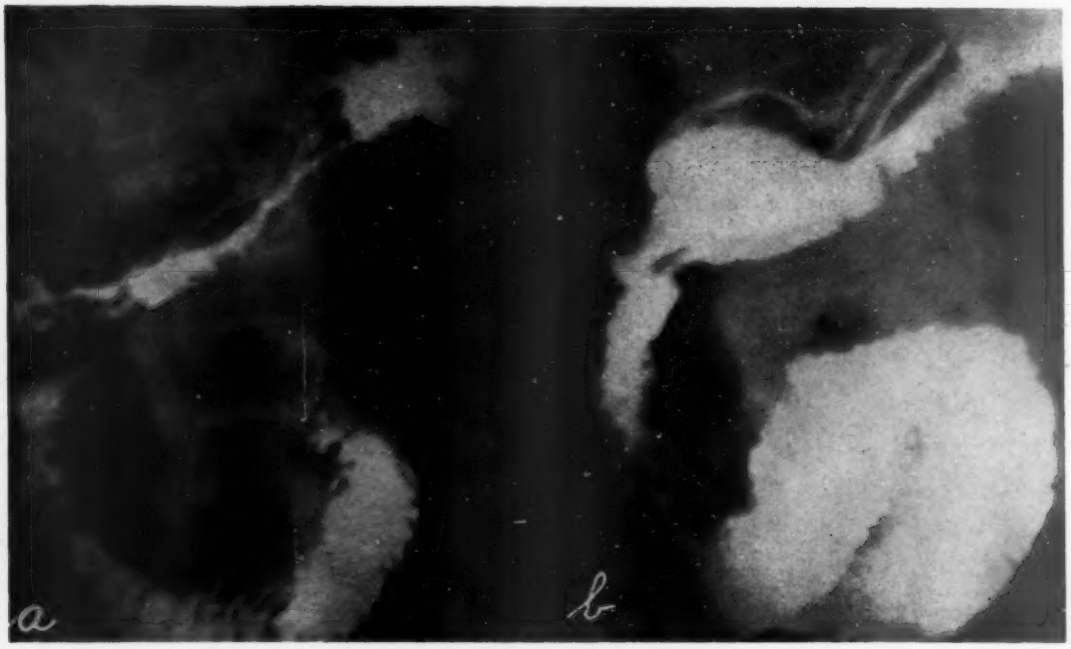


Fig. 30. *a*, pancreatitis. Marked swelling of head of pancreas. Duodenal dilatation. Spread of duodenal curve. *b*, same case, a little later, after further filling of stomach; no duodenal stenosis, but marked dilatation of jejunal loops. (Bade.)

If pancreatic stones are suspected, possibly the fact may be confirmed by stool and urine studies, there being an absence or marked diminution of pancreatic ferments in the stool and an enormous increase in the urine. The urinary normal of diastase was established by T. R. Brown in 1914. The urinary diastase in pancreatic lithiasis may be elevated to twenty times the normal.

Convulsive contraction of a circumscribed portion of the stomach, particularly regional gastrospasm of the prepyloric region, may be caused not rarely as a symptom of a painful, inflammatory, irritating condition within a neighboring organ, a distant symptom, generally looked upon as a visceral reflex, according to Bergmann.

This has been particularly observed with cholelithiasis, more rarely with renal stones, appendicitis, duodenal ulcer. Lüdin reports cases with such gastrospasm in the prepyloric region with pancreatic stone and with pancreatitis. Engelstad reports 2 cases of pancreatic calculi suspected on the basis of the roentgenograms showing a collection of stone shadows in the region of the pancreas, the outline of the collection of stones corresponding to the course of the pancreatic duct. In order to remove all doubt a duodenal sound was filled with contrast medium and inserted. It encircled the shadows, showing that they were really situated within the pancreas. Stereoscopic films should help to make the decision still more sure.

Probably a number of cases of pancreatic calculi are overlooked, being obscured because of the anatomical relationship of the pancreas to the stomach and intestines. With opaque medium in the stomach or bowel, the location of the pancreas is usually almost completely obscured in the gastrointestinal study. Only when the stones extend to the tail of the pancreas and project beyond the stomach shadow are they found under conditions of ordinary gastrointestinal investigation.

More systematic search for pancreatic stones should be made in view of the fact that they are associated with diabetes in a third of the cases. Labbe says that the chief

clinical features of a pancreatic lithiasis associated with diabetes are the pain, usually referred to the epigastric and left hypochondriac regions; the symptoms due to the absence of pancreatic digestion, such as fatty stools and diminution of pancreatic ferments in the secretion obtained with the duodenal tube; the shadows of the calculi; and the diabetes.

ACUTE PANCREATITIS

Special progress has been made in the diagnosis of acute pancreatitis. Bronner suggests that where there is a suspicion of acute pancreatitis, the operation be preceded by a short roentgen study with a few swallows of opaque material. I would suggest the use of umbrathor for this purpose, and also the making of a preliminary film of the abdomen, centering about the epigastrium but including the diaphragm and the pulmonary bases, as well as most of the abdomen. There have been observed elevation of the stomach, a transverse position of the duodenal bulb and enlargement of the duodenal loop, collection and stasis of appreciable quantities of the contrast material in the dependent portions of the duodenum, a defect in the shadow contours in the region of the duodenojejunal flexure, and beyond that again normal filling of the jejunal loops (Fig. 30). These changes are attributed to inflammatory swelling of the head of the pancreas. The stasis in the distal duodenum may be explained by mechanical causes or by the product of inflammatory processes in the immediate neighborhood of the duodenum whose tonus and motility are thereby damaged. There have also been observed by numerous well-known roentgenologists, especially abroad, sensitivity to pressure located in the pancreatic region, fullness between the stomach and the transverse colon, limitation of excursion of the left diaphragm and formation of pleural exudates and interlobar cicatricial adhesions especially on the left side (Fig. 31), ill-defined left psoas muscle contour, pressure-indentations in the stomach and duodenum, coarsely feathered duodenal mucosal relief, abnormal gas distention of the colon, sometimes a paralytic ileus with the formation of fluid levels in the intestines when the patient is examined in the erect or in the right-lying position. Gallstones or other evidences of gallbladder disease have been found. Some (Goldmann and others) believe they are able to show on a preliminary film a some-

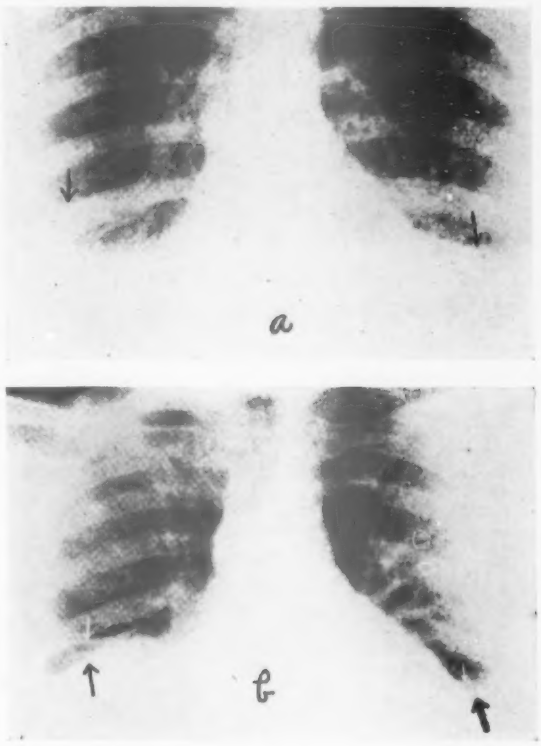


Fig. 31. Interlobar and basal exudates in acute pancreatitis (Hultén).

what indistinct shadow in the location of the pancreas from the size of the palm to a size twice that of a child's head, of the same density as the liver, set off by the gas-distended stomach above and the transverse colon below. Cole and Pound have reported similar findings in acute pancreatitis. In differential diagnosis between acute pancreatitis and perforation of a hollow viscus, such as perforating ulcer, a common forerunner of acute pancreatitis, the presence of air is sought under the diaphragm or under the lateral wall of the abdomen if the patient is too ill to be ex-

amined sitting erect. Edematous swelling of the pancreas may lead to some of these roentgen findings, and in some cases the sole roentgenological sign of an inflammatory disease of the pancreas may be an atony of the dependent portions of the duodenum, the cause of which is predominantly functional. De Takáts and Mackenzie have concurred in the reliability of some of the above-listed signs and urge more frequent use of the roentgen examination in cases of suspected acute pancreatitis.

Stetten feels that there is sufficient clinical evidence to warrant the belief that there is a subacute or mild pancreatitis, or so-called acute edema of the pancreas, which is entitled to recognition as a pathological and clinical entity, independent of frank, outspoken gallbladder disease, though it is most likely due to some primary disturbance of the biliary system. The clinical picture is rather characteristic: a definite history of previous recurrent attacks of pain, extending over a few months or years. The attacks vary in severity and duration and subside spontaneously until some serious accident occurs, such as frank hemorrhage, true suppuration or actual necrosis, or until a chronic pancreatitis is established. The roentgen findings are usually negative, but one ventures to believe that such cases should show the Frostberg inverted figure 3 sign or other changes of the character of the list given a few paragraphs earlier. Cholecystography ought to give aid.

CHRONIC PANCREATITIS

Chronic pancreatitis is characterized by a notable increase in the amount of connective tissue, the head of the organ in particular assuming an ultimate hardness, like cartilage, and a size as big as one's fist. It is not always the result of an inflammatory or infectious disease but may be the sequence of stasis due to pancreatic concretions in the principal excretory ducts or some other cause of retained pancreatic secretion.

When enlarged or hard enough to become palpable, it should be a relatively simple matter with our greatly increased possibilities of diagnostic technical achievement to arrive at some conclusion as to the presence of a pancreatic lesion. It is true that

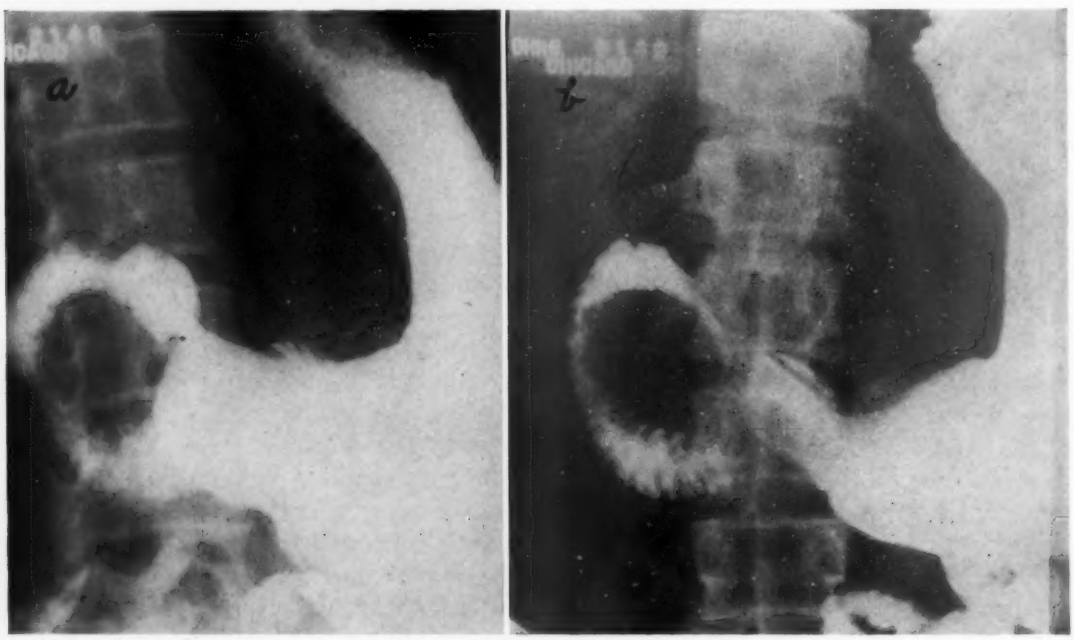


Fig. 32. Tumefaction of pancreas, especially caudal portion, in chronic pancreatitis secondary to cholelithiasis.

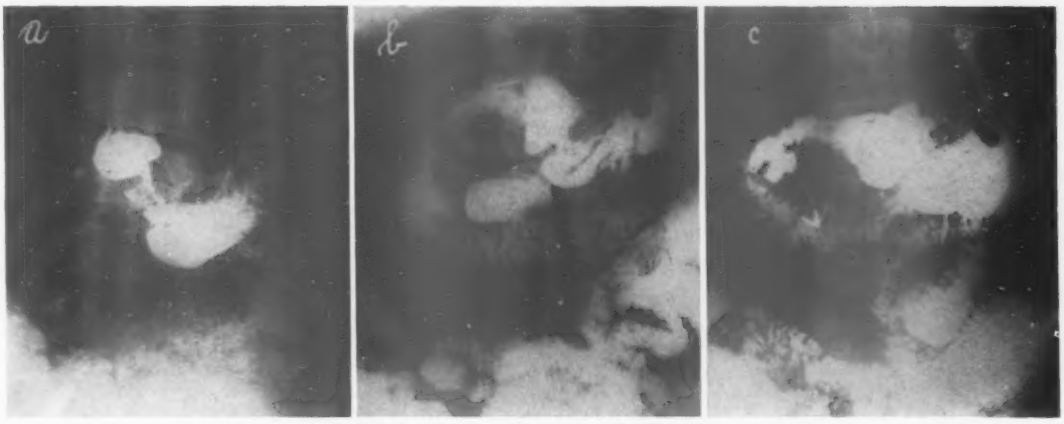


Fig. 33. Duodenal diverticula as a possible association of pancreatitis. *a*, small diverticulum near Vater's papilla. *b*, two diverticula, a small one near Vater's papilla and a large one in third portion of duodenum. *c*, double diverticulum (possibly two) near Vater's papilla.

the clinical laboratory procedures have also made great strides, and indications may be deduced from signs of pancreatic indigestion, but there is always a number of variables, differences in the motor and absorptive power of the intestine, and possibly the factor of the effect of enzymes of bacterial origin. Diastase estimations may be of great help; normal figures vary from 600 to 2,400 starch gram units, according to T. R. Brown, whereas in chronic pancreatitis the figures run from 120 to 300. The most impressive roentgen findings will be those of a tumor of the head of the pancreas (Fig. 32), but meticulous attention to the improvements brought about in roentgen technique during the last decade should develop signs of perivisceritis in the region of the duodenum, the pyloric portion of the stomach and in the jejunum, signs of cholecystitis and pericholecystitis, and roentgen evidence excluding other diseases in the vicinity.

Another finding sometimes recognized in chronic pancreatitis was reported by me in 1915, referable to duodenal diverticula and dilatation of the ampulla of Vater in several patients where there had been a chance to verify at operation the fact that the patient had a duodenal diverticulum (Fig. 33) lying in the second portion of the duodenum, on the concave side, and corresponding in location to the insertion of the common and pancreatic ducts. This had also been referred to by Åkerlund, Deaver, and more recently by Lindblom, Frentzel-Beyme, Haring, Herrnheiser, as well as by a number of French writers, who agree that there seems to be a connection between such a diverticulum of the duodenum and chronic pancreatitis. Very likely it is the dilated ampulla, which in some way contributes to the reflux of bile into the pancreatic duct. This may cause inflammation of the pancreatic duct with subsequent pancreatitis. Åkerlund saw necrosis of the pancreas in a case of this sort. His case is the more remarkable because sufficient of the opaque material had entered the terminal parts of the common and pancreatic ducts to visualize them on the roentgenogram. This made it possible to diagnose definitely the diverticulum-like structure such as the ampulla or diverticulum of Vater.

Haring, in a study of 34 cases of duodenal diverticulum, found in 16 roentgenologically demonstrable enlargements of the head of the pancreas. Most diverticula of the duodenum lie in or close to pancreatic tissue. Retention or stagnation of remnants of food is the chief factor, according to Haring, in bringing on inflammation of the wall; absence of a muscular layer in the diverticular wall is another factor. It may be extremely difficult to distinguish between a Vater's diverticulum filled with

opaque medium and a true duodenal diverticulum. In fact, the region of Vater's ampulla is a favorable site for the development of diverticula, the duodenal wall here being somewhat thinner and weaker than elsewhere. There are certain signs by which one may differentiate between diverticulum and Vater's ampulla, according to Lindblom (Fig. 34). A filled ampulla is usually seen in the mesial edge of the middle third of the descending limb of the duodenum,

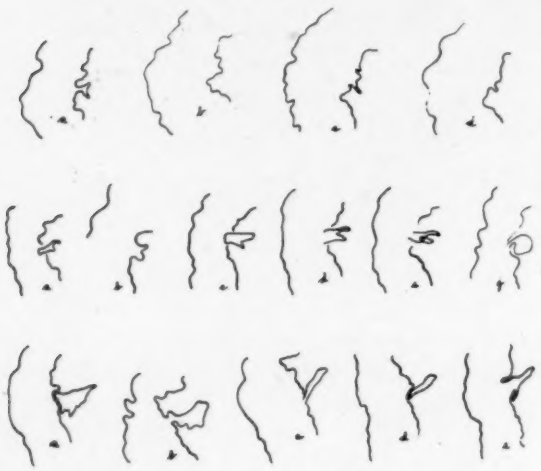


Fig. 34. Illustrating the changing conformation of a true diverticulum of Vater as contrasted with a paravaterian diverticulum. Upper row: *a*, tracing of a Y-shaped ampulla; *b*, *c*, *d*, three tracings from the same case. Middle row: tracing of an ampulla showing the confluence of choledochus and duct of Wirsung. Lower row: tracing of an ampulla filled with contrast emulsion. (Lindblom.)

thus differentiating from diverticula situated higher or lower, but not from paravaterian diverticula. The ampulla of Vater is richly supplied with muscle, and its size and form and emptying depend on the contraction of its musculature. The shadow varies considerably in dimension and form in a series of films, the changing aspect sometimes resembling a triangle or a cone, at other times being rounded or irregular. A diverticulum does not contract in a notable manner, though it may become distended and some change in form may result from pressure. In a series of films made without changing the patient's position, there is an invariable size and shape of the diverticular shadow. An ampulla filled with opaque material may even show the confluence of the pancreatic and common ducts; it is otherwise with diverticula, of course. The ampulla empties out its contents just as do the stomach and the duodenum, by its own contractions; the diverticulum does not empty by its own contractions. Therefore, a residue in the sac after clearance of the stomach and duodenum speak for a diverticulum whereas prompt clearance favors an ampulla filled with the opaque medium. Insufficiency of Vater's diverticulum is probably not a normal finding, as Lindblom found it in only 4 cases, all of pancreatitis, in a series of 1,400 duodenal examinations in a period of less than a year and a half. It is plausible that this phenomenon is related to the pancreatitis, either as a cause or as an effect. At any rate, when the roentgen examination indicates a possible insufficiency of Vater's diverticulum, one should think of and search for signs of chronic pancreatitis.

An acute inflammatory process commencing in a diverticulum of the second or third portion of the duodenum may result in serious pancreatic disease. A number of cases are on record in which this occurred. Therefore, as I pointed out in 1920, in a suspected pancreatic lesion where the barium study has revealed duodenal diverticula, it is of importance to determine the relation of the diverticulum to the pancreas, whether lying in front of, in the substance of, or behind the pancreas. By guided palpation under the fluoroscopic screen, or by stereoscopic films, it should be possible to determine this point in the majority of cases. With diverticula anterior to the pancreas it should be possible easily to express the contents of the sac by compression with the examining hand under the fluoroscopic screen; with diverticula lying in the substance or behind it, the examining hand is powerless to empty the sac of its contents. I have not yet found it possible to differentiate definitely between a diverticulum in the substance of the pan-

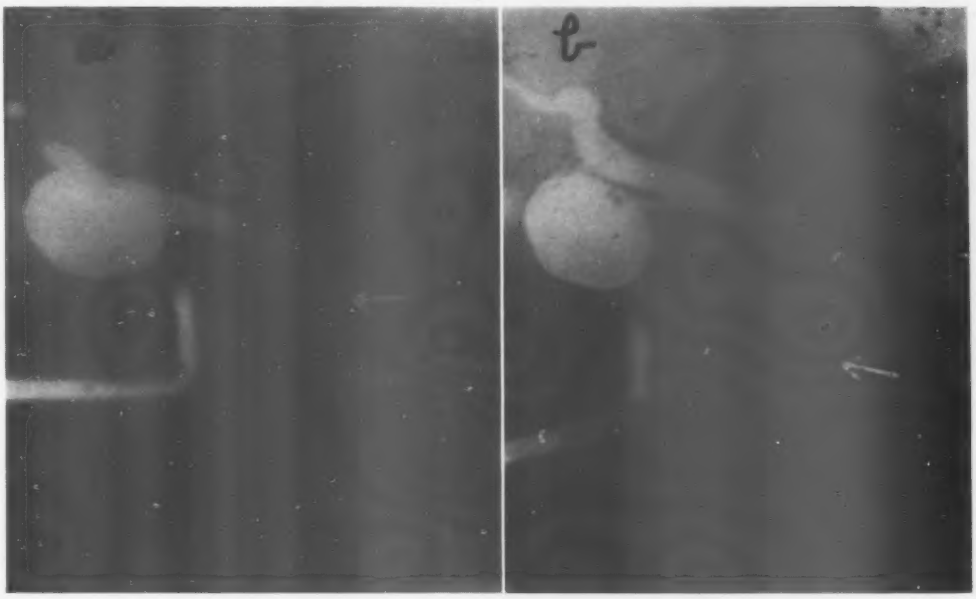


Fig. 35. Persisting stenosis of intrapancreatic portion of choledochus, as visualized through biliary fistula, following cholecystostomy. Chronic pancreatitis.

creas and one behind it. Possibly in the retropancreatic diverticulum there should be slight mobility on deep respiration. The surgical removal of a diverticulum lying within the substance of the pancreas is very difficult but quite possible by the technique devised by Neil J. MacLean. For diverticula lying outside the substance of the pancreas, the operation of diverticulectomy is quite simple, once the sac is located. Sacs lying behind the pancreas are very likely to escape observation, even careful search, at operation without the guidance furnished by the roentgen examination.

There are numerous cases of penetration of the pancreas by ulcers of the stomach or duodenum. Such penetrating ulcers should always suggest the need of special investigation of the pancreas, though it must be said that it is rare to recognize severe lesions of the pancreas resulting from such penetration. It is possible that minor disturbances are more frequent than we realize. Mayo-Robson reported the histological picture of interstitial pancreatitis around ulcers penetrating into the pancreas. The roentgen signs of invasion of the pancreas by gastric and duodenal ulcers are classical. When the ulcer niche fails to move perceptibly up and down on respiration, the conclusion is warranted that invasion of the pancreas has occurred; ulcers penetrating into the liver substance show mobility of the ulcer niche on respiration corresponding to the excursion of the liver.

Reference has been made to visualization of the pancreatic ducts. Schmieden and Sebening published a number of roentgenograms made on cadavers showing the variations of the course and arrangement of the pancreatic excretory ducts (Fig. 1). But in the living it is a frequent occurrence for the pancreatic duct to fill in the course of a cholangiography, either when the opaque material is introduced through a biliary fistula (Fig. 2) or when it is introduced in the course of a cholangiography done in the midst of an operation. When operation reveals a tumefaction or other evidence of disease of the head of the pancreas and the surgeon is unable to make a definite differentiation between carcinoma and pancreatitis (Fig. 35), a biliary fistula may be produced for the purpose of subsequent studies, in the hope that the pancreatic ducts may become visualized. I have often

followed this procedure. If, on repeated examinations, the permeability of the common duct does not return, the conclusion is warranted that the stenosis is probably carcinomatous. This is a method already in considerable vogue in this country, thanks to the impetus given it by Hunt and his colleagues.

Early in 1925 I suggested the value of the emptying time of the gallbladder after cholecystography in the study of pancreatic disease. Cholecystography may be utilized in pancreatic diagnosis in at least two ways:

1. When the gallbladder fills, the distortion produced by compression between the liver and the enlarged pancreas, and perhaps also the indurated duodenal wall, will contribute to the sum of evidence against the pancreas.

2. When one studies by cholecystography a case of relative but not high grade common duct compression by the hardened pancreatic head, the result is a very large gallbladder of normal contours, with faint density, which may grow more dense as the hours pass, in spite of efforts to empty the gallbladder by a fat meal, duodenal instillation of magnesium sulphate or otherwise (Figs. 36 and 37). This furnishes the proof of cholecystic stagnation often not appreciable on percussion or palpation.

A matter of great interest was the cholecystographic response in cases of cancer of the pancreas studied by Ransom. In a series of 25 non-icteric patients cholecystography was employed 9 times with the following results: non-visualization of the gallbladder in 5, normal without stone in 3, and an unsatisfactory test in one. Of the jaundiced patients, 84 in number, 56 had cholecystography with the following results: non-visualization (complete absence of shadow) 49, faint visualization 2, normal without stone 3, unsatisfactory examination 2.

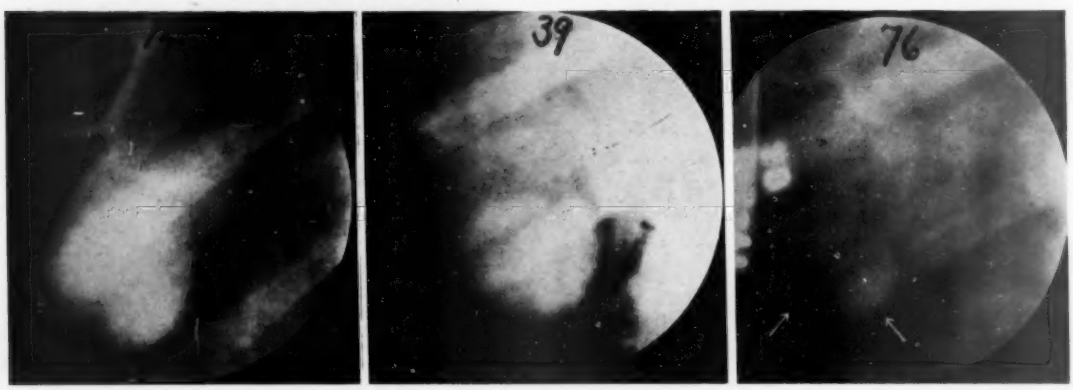


Fig. 36. Carcinoma of the pancreas. Cholecystograms shown at 14, 39, and 76 hours after intravenous injection of iodeikon prove gallbladder distention and marked biliary stasis in the gallbladder.

Borak and others have called attention to still another finding in connection with cholecystography in cases of pancreatic tumor. In addition to the signs of enlargement and slow emptying of the gallbladder which I described, in early cases there is a shadow-producing contrast reservoir in the region of the hepatic flexure, a finding, naturally, of significance only when the intravenous method is employed for the introduction of the gallbladder dye. In advanced cases there was no gallbladder visualization (absence of shadow) and no intestinal reservoir formation.

RADIATION THERAPY OF PANCREATIC DISEASE

The radiation therapy of pancreatic pathology is still a rather unsatisfactory problem. Briefly, I may say that I have had

fair results in the treatment of what I believed to be chronic pancreatitis, with failures in those cases which ultimately proved to be neoplastic.

The length of useful and comfortable life has been prolonged over that which would otherwise be the lot of the unfortunate victims of pancreatic carcinoma.

Pack and his colleagues of the Memorial Hospital, New York City, have reported on the radiation therapy of 23 cases of pancreatic carcinoma treated in the years 1922

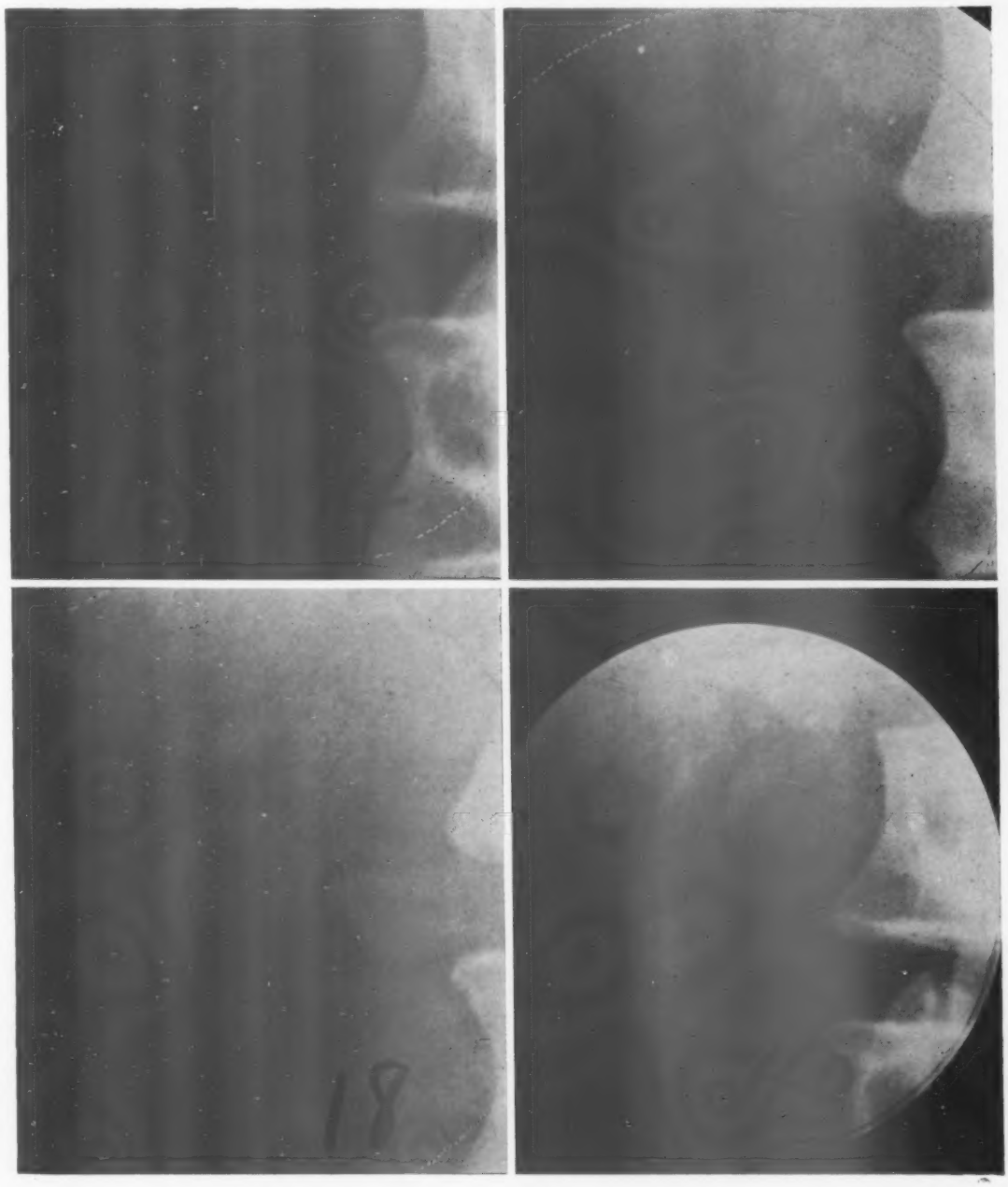


Fig. 37. Cholecystographic findings in carcinoma of pancreas (same case as Fig. 16). Persisting gallbladder visualization. Spastic gallbladder contractions accompanied by subjective cramps, relieved by palliative cholecystoduodenostomy. Patient had also a duodenojejunostomy.

to 1937. Most of the cases received roentgen treatment at 200 kv. and some had radium pack therapy. The average duration of life in all cases was a little over eight months following completion of the irradiation. One treated at 700 kv. lived seventeen months. Eight had a very definite palliation with improved appetite and gain in weight for an average of 17.2 months after completion of the treatment. In 6 there was a definite regression of the tumor. Another had twenty-eight months of life from the time of ending the treatment. Most remarkable was the disappearance of all evidence of diabetes following the external irradiation over the pancreatic cancer; when the tumor recurred with jaundice, the diabetes recurred. Another had sixteen months of palliation. A woman of sixty-four with painless jaundice had a cholecystoduodenostomy, and a radium pack treatment of 100,000 mg-hr. per portal. The tumor disappeared and the duodenal loop lost its wide spread. Result: No palpable tumor for two and a half years, total duration of life from radiation therapy to death three and a half years.

Lahey and MacKinnon in an experience with 47 cases of carcinoma of the head of the pancreas, emphasize the fact that radiotherapy is of value, inasmuch as those receiving it lived on an average of seventeen months, while those not receiving it lived eight and a half months. These figures coincide very closely with the results obtained at the Memorial Hospital.

Irradiation has also been used for a variety of benign conditions, such as diabetes, asthma, and for certain anticipated endocrine effects. The basis for this treatment is still somewhat empirical, and the future must be looked to for further elucidation of the rationale of such practice.

You have accompanied me in a review of the more important findings relative to the roentgen diagnosis of the pancreas. Some of the ground does not strike one as being any too safe for reckless or headlong going, but the way is pointed out to a more comprehensive study of cases of suspected pancreatic disease. We may deduce the lesson that patience and meticulous attention to technical detail in our examinations is a requisite to the reward of better diagnostic and therapeutic results.*

REFERENCES

Åkerlund, Å. Duodenaldivertikel und gleichzeitige Erweiterung des Vaterschen Divertikels bei einem Fall von Pankreatitis. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1917–1918, *25*, 540–550.

Alvarez, W. C. Peristalsis in health and disease. First Caldwell Lecture, 1920. Am. J. Roentgenol., 1921, *8*, 1–11.

Aschoff, L. Pathologische Anatomie. Third edition. II, p. 922.

Assmann, H. Röntgenographische Nachweis von Pankreassteinen. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1911–1912, *18*, 242–244.

Bade, H. Die Bedeutung des Röntgenverfahrens für die Diagnostik akuter Oberbaucherkrankungen. *Röntgenpraxis*, 1939, *11*, 216–222.

Berg, H. H. Röntgenuntersuchungen am Innenrelief des Verdauungskanals. G. Thieme, Leipzig, 1930, p. 98.

Bird, C. E. Tumors which may expand the curvature of duodenum, particularly tumors and infections of retroperitoneal lymph nodes. *Ann. Surg.*, 1929, *89*, 12–29.

Bittorf, A. Abscess in omental sac after necrosis of the pancreas. *Mitt. a. d. Grenzgeb. d. Med. u. Chir.*, 1913, *26*, 109.

Borak, J. Cholecystography as a method of diagnosing tumors of head of the pancreas. *Wien. klin. Wchnschr.*, 1935, *48*, 399–400.

Borak, J. Cholecystographic symptoms in tumors of the pancreas. *Mitt. d. Gesellsch. f. inn. Med.*, 1935, *34*, 1.

Borak, J. Roentgen diagnosis of pancreatic tumor. *Wien. klin. Wchnschr.*, 1937, *50*, 1428–1429.

Bottin, J. Troubles detèrminés chez le chien par la suppression ou la perte complète de la sécrétion externe du pancréas. *J. belge de gastro-enterol.*, 1936, *4*, 229–250.

Bottin, J. Réflexions sur la maladie dénommée pancréatite aiguë chez l'homme. *Presse méd.*, 1938, *46*, 142–143.

Bronner, H. Roentgen diagnosis of acute pancreatitis. *Zentralbl. f. Chir.*, 1928, *55*, 2436–2440.

Brown, T. R. Diseases of the pancreas—clinical aspect. *Am. J. Digest. Dis. & Nutrition*, 1936, *3*, 682–685.

Buckstein, J. Tumor of the body of the pancreas. *J. Am. M. Ass.*, 1925, *85*, 1061.

* Editor's Note: Following the Lecture Dr. Case was presented by President E. L. Jenkinson with the Gold Medal of the Society, bearing the inscription "Pioneer in Radiology, Caldwell Lecturer, 1939."

Carelli, H. H. Personal communication.
Case, J. T. Roentgen observations on the duodenum with special reference to lesions beyond the first portion. Am. J. Roentgenol., 1916, *3*, 314–326.
Case, J. T. Diverticula of the small intestine, other than Meckel's diverticulum. *J. Am. M. Ass.*, 1920, *75*, 1463.
Case, J. T. A review of three years' work and articles on pneumoperitoneum. Am. J. Roentgenol., 1921, *8*, 714–721.
Case, J. T. Roentgenologic examination in pancreatic disease. *Tr. Am. Gastro-enterol. Ass.*, 1928.
Clute, H. M. Problem of cancer of the pancreas. *J. Am. M. Ass.*, 1936, *107*, 91–97.
Cole, L. G., and Pound, R. E. Small intestine—inflammatory lesions and accompanying reactions. *Radiology*, 1936, *27*, 330–338.
Colp, R., and Doubilet, H. Clinical significance of pancreatic reflux. *Ann. Surg.*, 1938, *108*, 243–262.
Colp, R., and Doubilet, H. Operative incidence of pancreatic reflux in cholelithiasis. *Surgery*, 1938, *4*, 837–846.
Crane, A. W. Skiagraphic delineation of the head of the pancreas. Read before American Roentgen Ray Society, 1910.
Engel, A., and Lysholm, E. Contribution to study of symptomatology of pancreatic cancer. *Acta med. Scandinav.*, 1933, *80*, 34–42.
Engel, A., and Lysholm, E. New roentgenological method of pancreas examination and its practical results. *Acta radiol.*, 1934, *15*, 635–651.
Engelstad, R. B., and Römcke, O. Diagnosis of pancreas stones. *Acta radiol.*, 1936, *17*, 79–84.
Feldman, M. Roentgen diagnosis of early enlargement of head of the pancreas. *Am. J. Digest. Dis.*, 1939, *6*, 237–238.
Frentzel-Beyme, A. Duodenaldivertikel und Pankreatitis. *Med. Klin.*, 1934, *30*, 1296–1299.
Frostberg, N. Characteristic duodenal deformity in cases of different kinds of peri-vaterial enlargement of the pancreas. *Acta radiol.*, 1938, *19*, 164–173.
Garrod, A. Quoted by Brown.
Gillespie, Marjorie. Carcinoma of the pancreas. *Glasgow M. J.*, 1939, *131*, 118–121.
Goldmann, C. H. Roentgen diagnosis of acute pancreatitis. *Röntgenpraxis*, 1931, *3*, 793–796.
Guleke. Die neuen Ergebnisse in der Lehre der akuten und chronischen Erkrankungen des Pankreas mit besonderer Berücksichtigung der entzündlichen Veränderungen. *Ergebn. d. Chir. u. Orthop.*, 1911, *4*, 409. *Verhandl. f. Verdauungs- und Stoffwechsellkrankheiten*, 1925, p. 113.
Haenisch, F. Die Röntgenuntersuchung bei Pankreaserkrankungen. In Rieder and Rosenthal: Lehrbuch der Röntgenkunde. Second edition. 1925, p. 402.
Haring, W. Die Erkrankungen der Bauchspeicheldrüse im Röntgenbilde. *Ergebn. d. med. Strahlenforsch.*, 1933, *6*, 407–458.
Haring, W. Röntgenuntersuchung des Pankreas. *Med. Welt*, 1934, *8*, 1579–1580.
Harper, M. H. Congenital steatorrhoea due to pancreatic defect. *Arch. Dis. Childhood*, 1938, *13*, 45–56.
Herrnheiser, G. Ueber die Manifestationen von Pankreaserkrankungen im Röntgenbilde. *Med. Klin.*, 1922, *18*, 233.
Hershenson, M. A. Carcinoma of the tail and body of the pancreas; roentgenologic technique for its demonstration. *Am. J. Digest. Dis. & Nutrition*, 1936–1937, *3*, 835–839.
Hessel. Proceedings of the Twelfth German Röntgen Congress, April, 1921. *München. med. Wchnschr.*, 1921, *68*, 472.
Hick, F. K., and Mortimer, H. M. Carcinoma of the pancreas. *J. Lab. & Clin. Med.*, 1934, *19*, 1058–1067.
Hicken, N. F., Best, R. R., and Hunt, H. B. Cholangiography; visualization of gallbladder and bile ducts during and after operation. *Ann. Surg.*, 1936, *103*, 210–229.
Hickey, P. M. The Caldwell Lecture, 1928. Am. J. Roentgenol. & Rad. Therapy, 1931, *25*, 177–195.
Hörhammer. Pankreascysten. *München. med. Wchnschr.*, 1916, *43*, 1126.
Hultén, O. Beitrag zur Röntgendiagnose der akuten Pankreasaffektionen. *Acta radiol.*, 1928, *9*, 222–254.
Hultén, O. Cholangiographie während der Operation. *Deutsche Ztschr. f. Chir.*, 1938, *250*, 484–513.
Hunt, C. J. Cysts of the pancreas. *Tr. Western Surg. Ass.*, 1937, pp. 446–458.
Judd, E. S. Mattson, H., and Mahorner, H. R. Pancreatic cysts; report of 47 cases. *Arch. Surg.*, 1931, *22*, 838–849.
Katsch, G., and Brinck, J. Die Krankheiten der Bauchspeicheldrüse. Handbuch der inn. Med. Third edition. Vol. II. J. Springer, Berlin, 1938, pp. 1019–1102.
Köhler, A. Röntgenology. Second English edition. Translated and edited by Arthur Turnbull. Wm. Wood & Co., Baltimore, 1935, p. 449.
Körte. Die Chirurgie des Pankreas. Handbuch d. prakt. Chirurgie, by Garré, Kultner, Lexer. Bd. 3, 1923.
Körte. Quoted by Robert Coope. The Diagnosis of Pancreatic Disease. Oxford University Press, New York, 1927.
Kreuzfuchs, S. Die Magenmotilität beim Ulcus duodeni. *Deutsche med. Wchnschr.*, 1912, *38*, 2168.
Labbe, M. Lithiase pancréatique et diabète. *Arch. d. mal. de l'app. digestif*, 1938, *28*, 913–934.
Lahey, F. H., and MacKinnon, D. C. Carcinoma of the pancreas. *Surg. Clin. North America*, 1938, *18*, 695–704.
Leven, N. L. Experimental study; effect of radium emanation on pancreas of dogs. *Am. J. Cancer*, 1933, *18*, 899–904.

Lindblom, A. F. Des altérations roentgenologiques de l'estomac et du duodénum dans les pancréatites. *Acta radiol.*, 1928, *9*, 255–265.

Lüdin, M. Roentgen examination of diseases of the pancreas. *Schweiz. med. Wchnschr.*, 1934, *64*, 692–695.

Lüdin, M. Pancreatic stones in roentgenogram. *Röntgenpraxis*, 1936, *8*, 462–463.

Lüdin, M. Regional gastrospasm due to pancreatic disease (inflammation and lithiasis). *Acta radiol.*, 1938, *19*, 348–351.

Maclean, N. J. Diverticulum of duodenum, with report of case, in which the diverticulum was imbedded in head of the pancreas, and method for its removal. *Surg., Gynec. & Obst.*, 1923, *37*, 6.

Martina, A. Ueber chronische interstitielle Pankreatitis. *Deutsche Ztschr. f. Chir.*, 1907, *87*, 499.

Mayo-Robson, A. W. Pathology and surgery of certain diseases of the pancreas. *Lancet*, 1904, *1*, 911.

Mayo-Robson, A. W., and Cammidge, P. J. The Pancreas, Its Surgery and Pathology. Southworth Publishing Co., New York, 1907, p. 374.

Mehnen, H. Die Bedeutung der Mündungsverhältnisse von Gallen- und Pankreasgang für die Entstehung der Gallensteine. *Arch. f. klin. Chir.*, 1938, *192*, 559–571.

Orndoff, B. H. Pneumoperitoneum in x-ray diagnosis. Abs. in Am. J. Roentgenol., 1920, *7*, 173.

Pack, G. T., and McNeer, G. Radiation treatment of pancreatic carcinoma. Am. J. Roentgenol. & Rad. Therapy, 1938, *40*, 708–714.

Paul, L. W. Roentgen diagnosis of carcinoma of the pancreas. *Am. J. Cancer*, 1936, *28*, 720–734.

Peutz, J. L. A. Zur Differentialdiagnose der Pankreolithiasis. *Deutsche med. Wchnschr.*, 1923, *49*, 178.

Ransom, H. K. Carcinoma of pancreas and extrahepatic bile ducts. *Am. J. Surg.*, 1938, *11*, 264–281.

von Redwitz, E. Beobachtungen und Erfahrungen in zwei Fällen von Pankreascyste. *Arch. f. klin. Chir.*, 1926, *140*, 501–517.

von Redwitz, E. Recognition and treatment of cyst of the pancreas. *Schweiz. med. Wchnschr.*, 1935, *65*, 42–45.

Ruth, C. E. Transperitoneal retrogastric surgery with report of a case of pancreatic calculi and one of retrogastric sarcoma. *Colorado Med.*, 1906, 421.

Sante, L. R. Detection of retroperitoneal masses by aid of pneumoperitoneum. Am. J. Roentgenol., 1921, *8*, 129–134.

Schlesinger, E. Zur Bewertung der Röntgenuntersuchung bei der Diagnose von Pankreascysten. *Med. Klin.*, 1912, *8*, 1027.

Schmieden, V., and Sebening, W. Chirurgie des Pankreas. *Arch. f. klin. Chir.* (Kongressbericht), 1927, *148*, 319–387.

Shupman. Quoted by Oser, L. Carcinoma Pankreas. In: Nothnagel's Spezielle Pathologie und Therapie, 1898, *18*, 85.

Stein, A., and Stewart, W. H. Pneumoperitoneal Roentgen Ray Diagnosis. Southworth Publishing Company, New York, 1921.

Stenström, B. Polypoid colon relief; roentgenologic symptoms in pancreas affections. *Acta radiol.*, 1935, *16*, 589–595.

Stetten, De W., Subacute pancreatitis or so-called acute oedema of the pancreas. *Ann. Surg.*, 1930, *92*, 248–262.

de Takáts, G., and Mackenzie, W. D. Acute pancreatic necrosis and its sequelae. *Ann. Surg.*, 1932, *96*, 418–440.

Wiese, H. W., and Larimore, J. W. Roentgenology of extra-alimentary tumors. Am. J. Roentgenol. & Rad. Therapy, 1932, *27*, 383–404.

Wolff, E. Pankreascysten und -pseudocysten. *Beitr. z. klin. Chir.*, 1911, *74*, 1.

VOL. 44, NO. 4

RECENT ADVANCES IN ROENTGEN EXAMINATION OF THE NECK

BODY SECTION ROENTGENOGRAPHY (PLANIGRAPHY) OF THE LARYNX*

By BARTON R. YOUNG, M.D.
PHILADELPHIA, PENNSYLVANIA

THE SOFT tissue structures of the neck are rendered visible by roentgenograms because the surface covering of most of them is thrown into relief by the air content of the pharynx, larynx and cervical trachea. This is not true of the cervical esophagus, hypopharynx, pyriform sinuses and epiglottic valleculae, which are best studied by the use of opaque mixtures. The diagnostic value of a thorough roentgen examination of the neck is not generally appreciated because, until recent years, the only satisfactory roentgenograms of this region were the lateral projections. The improvement in film contrast and the advent of the fine focus shock-proof roentgen tube make it possible to obtain ventral projections of the larynx while, if the body section method is used, satisfactory anteroposterior planigraphic roentgenograms are obtained. Studies made with this latter method are very valuable to delineate soft tissue abnormalities particularly tumors of the larynx.

Almost all of the information that is available in the literature concerning roentgen examination of the soft tissues of the neck is based on observations made with the patient in the lateral position. The lateral study enables visualization of the base of the tongue, epiglottic valleculae, pharynx including posterior pharyngeal wall, hyoid bone, epiglottis, aryepiglottic folds, the hyaline cartilages of the larynx which are the thyroid, cricoid and arytenoids, the arytenoid soft tissue mass around the cartilages, the true and false cords, and the spaces between the cords called the laryngeal ventricles (Fig. 1). The ventricles are cigar- or zeppelin-shaped

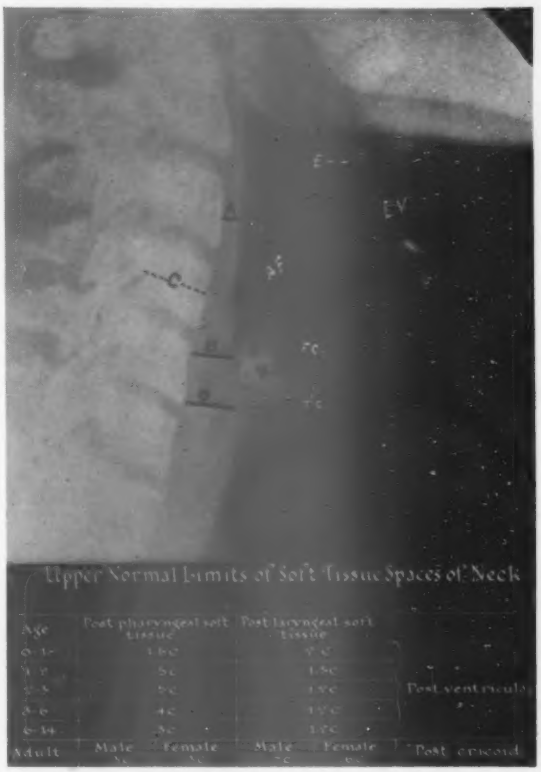
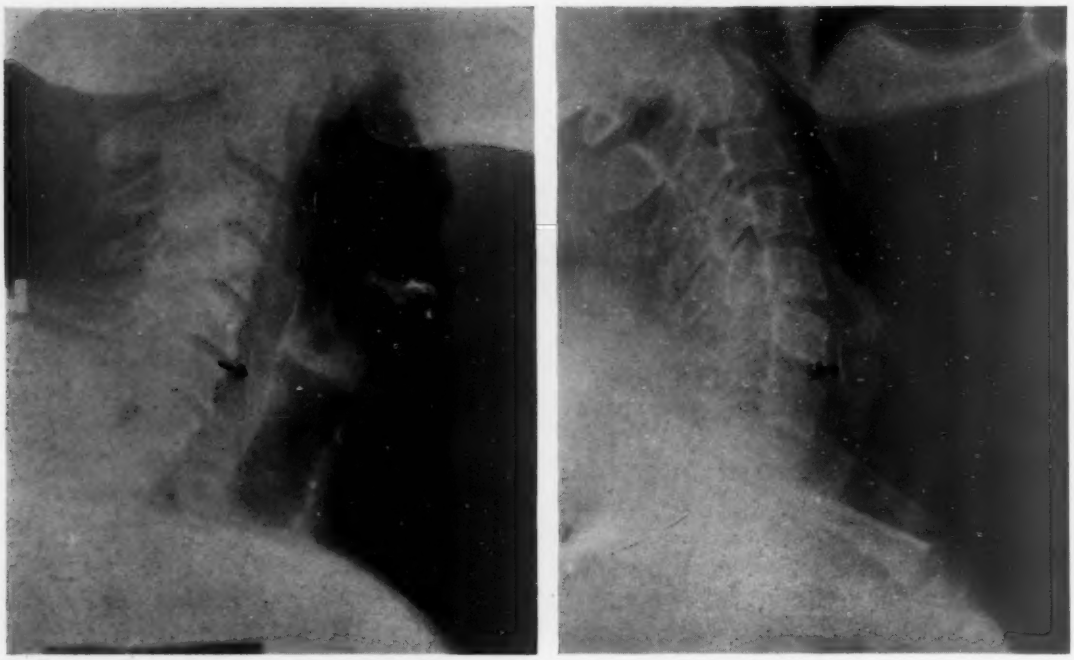


FIG. 1. Composite illustration of roentgenogram of normal neck and chart of soft tissue measurements. *V*, ventricle; *FC*, false cord; *TC*, true cord; *AF*, aryepiglottic fold; *EV*, epiglottic vallecula; *E*, epiglottis. Soft tissue zone in back of airway at *A*, post-pharyngeal; *B*, post-ventricular; *O*, post-cricoid. *C* is anteroposterior dimension of fourth cervical vertebral body.

spaces located on either side of the midline, each bounded above by the false cord and below by the true cord. The ventricles are

* From the Department of Radiology, Temple University Medical School, Philadelphia. Submitted to Faculty of School of Medicine of Temple University as partial requirement for Master of Science Degree in Radiology. Read at the Fortieth Annual Meeting, American Roentgen Ray Society, Chicago, Ill., Sept. 19–22, 1939.



A *B*

Fig. 2. Incomplete linear ossification in cricoid cartilage simulating foreign body indicated by arrow in *A*. Shadow, *FB*, in similar position in *B* is a fragment of chicken bone in food passage.

Fig. 3. Circular defect, indicated by arrows, in lamina of *normal* thyroid cartilage is a common finding due to incomplete ossification and does not represent an area of destruction.

usually seen well during the phonation of "e" or "a." Immediately in back of the posterior extremity of each true cord is a spherically shaped soft tissue shadow normally about 0.5 cm. in diameter which represents the arytenoid mass. The aryepiglottic folds extend from the arytenoids to the posterolateral aspects of the epiglottis. This latter structure is well demonstrated in the lateral plane so that any change in its shape due to disease is easily detected.

In a previous article, Chamberlain and I described in detail the process of ossification in the laryngeal cartilages and pointed out that irregular ossification, particularly in the posterior aspect of the cricoid, is occasionally mistaken for a bony foreign body in the food passage (Fig. 2). Ossification starts as early as the age of twenty in the postero-inferior aspect of the thyroid cartilage, and progresses slowly and irregularly cephalad along the posterior margin and anteriorly along the inferior extremity of each lamina. An unossified portion of the thyroid cartilage has been mistaken for an area of destruction during observation and treatment of cancer of the

larynx (Fig. 3). The bony centers in the thyroid cartilage may interfere with visualization of the laryngeal ventricles in the lateral projection, especially in the male, but since the median portion of the cartilage does not ossify, the ventricles and cords can be seen by study of the ventral projection (Fig. 6*A*).

It is extremely important that the normal dimensions of the soft tissue spaces be kept in mind as the question frequently arises as to the existence of retropharyngeal or retrolaryngeal abscess or phlegmon. In addition to infection, non-opaque foreign bodies and neoplasm must be suspected if one of the soft tissue spaces is widened. For the convenience of the reader, there is included a composite illustration which consists of a chart showing the upper normal limits of soft tissue spaces of the neck photographed on an unexposed lower portion of a lateral roentgenogram of the neck. The soft tissue measurements are taken from Hay's monograph. We have used this chart for years, and find it invaluable for quick reference during routine film interpretation (Fig. 1).

Although many of the non-neoplastic affections of the larynx cannot be diagnosed by roentgen study alone, a few of them produce changes which are characteristic. Laryngoscleroma (oftentimes rhino-laryngo-tracheal scleroma) can be diagnosed by lateral studies of the neck due to the characteristic narrowing of the subglottic and cervical tracheal air shadow along with the thickening of the laryngeal structures and post-tracheal soft tissue zone. The tracheal walls appear to be coated with a layer of tissue much like icing on a cake. Our patients improved markedly after roentgen treatment, and subsequent films showed a much improved airway (Fig. 4).

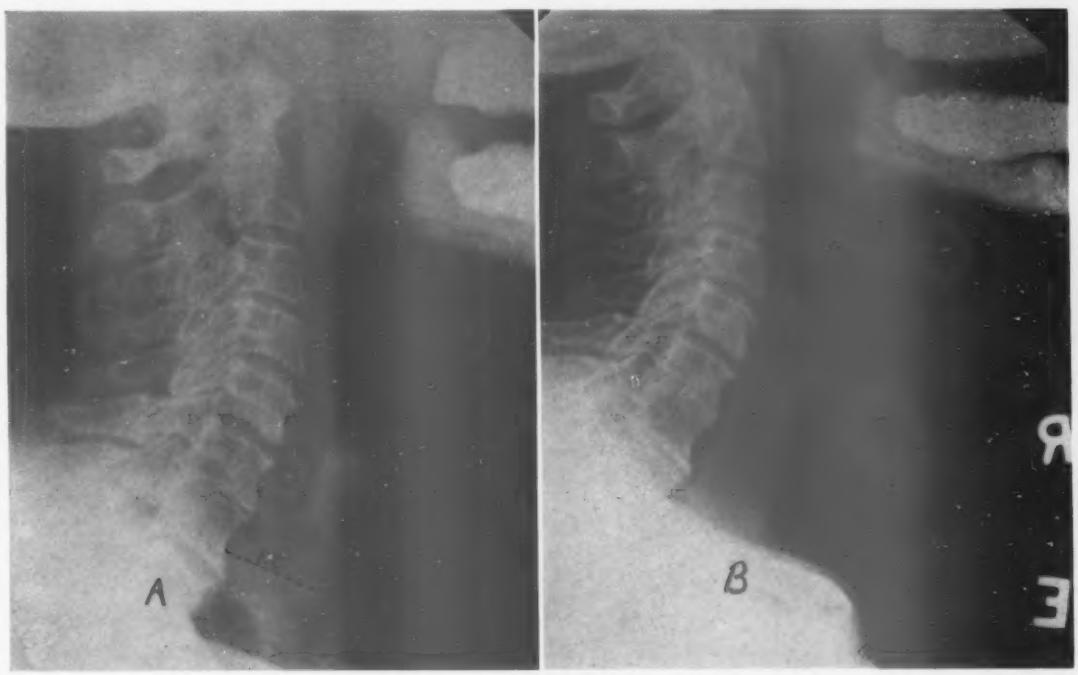


Fig. 4. Laryngotracheal scleroma before and after roentgen treatment. *A*, before treatment; note narrowing of trachea, thickening of laryngeal soft tissues and widening of post-tracheal soft tissue zone, *PT*. *B*, improvement six weeks after administration of six 150 r weekly treatments to each side of neck evidenced by increase in lumen of trachea.

Any change in contour of the mucosal surface of the air passage or unusual or asymmetrical enlargement of one of the laryngeal structures is suggestive evidence

of a new growth. In some locations, such as the base of the tongue, epiglottis, aryepiglottic folds, posterior pharyngeal wall and cervical trachea, visualization of a tumor is usually quite satisfactory by the lateral projection.

Neoplasm of the hypopharynx and cervical esophagus may be suspected if the post-laryngeal and post-tracheal soft tissue zones are increased, but in order to be certain of the diagnosis, an opaque mixture must be swallowed by the patient. Irregularity of the lining mucosa, narrowing or obstruction of the food passage, and deviation from its usual course, are the usual findings when the food passage is invaded by carcinoma.

Tumors of the cervical trachea are not common, and are easily recognized by the lateral projection unless they are located at the thoracic inlet where the shoulders may interfere. If the tumor is on a plane with the shoulders and therefore difficult to visualize, it is possible that the coughing or swallowing act will cause it to move cephalad and thereby enable better visualization (Fig. 5).

The discussion up to this point is restricted to the information that is available from roentgen studies with the patient in the lateral position. Although such studies are invaluable, they do not indicate the location of a lesion as to side, nor do they allow estimation of its size or extent from side-to-side. Since the introduction of shock-proof roentgen tubes, we have obtained ventral projections of the neck and larynx, using a short target film distance in order to deliberately blur the spine shadow and thus render the laryngeal structures visible (Fig. 6*A*). The cone fitting or window of the tube is placed against the back of the patient's neck so that the central ray passes in a horizontal plane through the

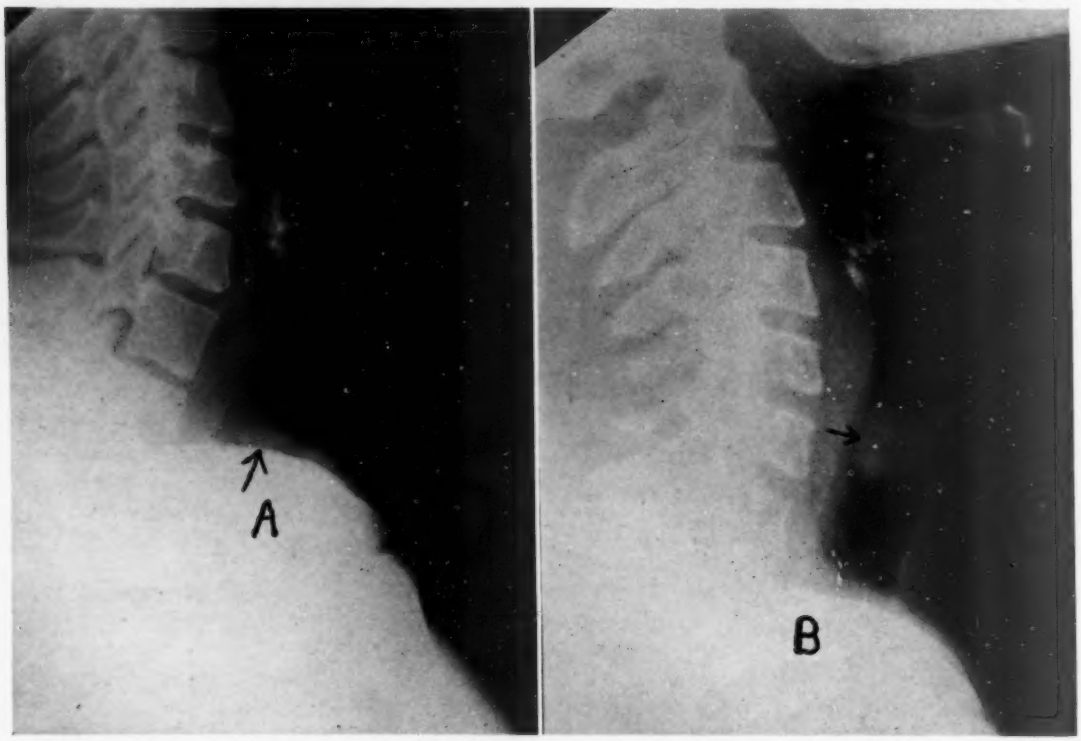


Fig. 5. Fibroma of cervical trachea. *A*, tumor seen just above level of clavicle. *B*, roentgenogram exposed at height of cough to obtain better visualization.

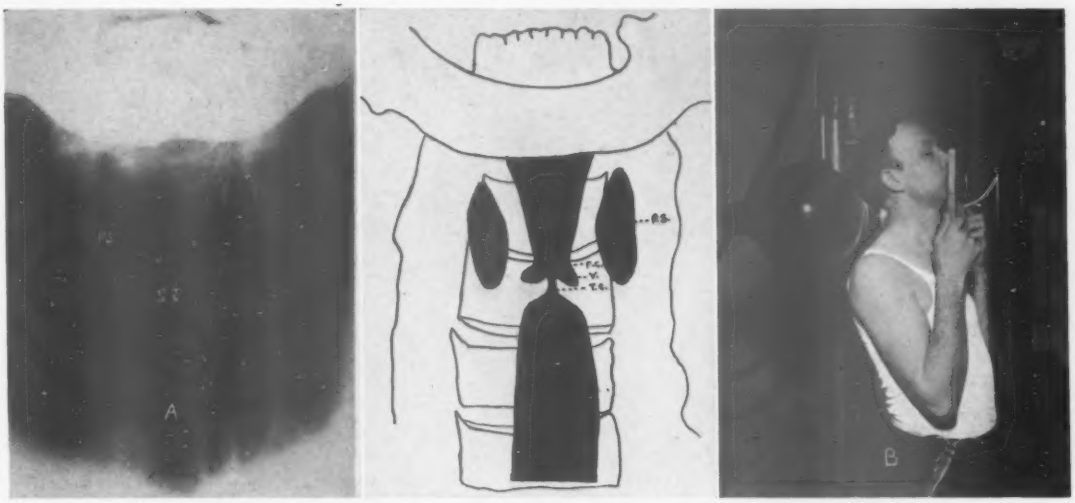


Fig. 6. *A*, ventral projection of normal larynx exposed during phonation of "e" at short target film distance. *PS*, pyriform sinus; *V*, ventricle; *FC*, false cord; *TC*, true cord; *G*, rima glottis. *B*, photograph showing position of tube and film for ventral projection of larynx.

middle of the thyroid cartilage (Fig. 6*B*). The target-skin distance is only 10 cm., while the target-film distance amounts to this figure plus the posteroanterior dimension of the neck. We are using kilovoltages varying from 45 to 50, 300 ma., and 1/20 second exposures. Films are exposed after respiration has been suspended, and during the phonation of "e" in order to determine the range of motion of the cords. Many of the laryngeal structures are paired so it is relatively easy to lateralize a lesion with this projection, and to demonstrate any deviation of the airway and food passage.

Valuable information concerning the larynx is obtained by films exposed with this technique. Absence of motion of one of the true cords due either to recurrent laryngeal nerve paralysis or to fixation by tumor can be demonstrated by comparing a film exposed during the phonation of "e" with one made while the larynx is at rest. During phonation the airway is deviated to the diseased side and the involved true cord

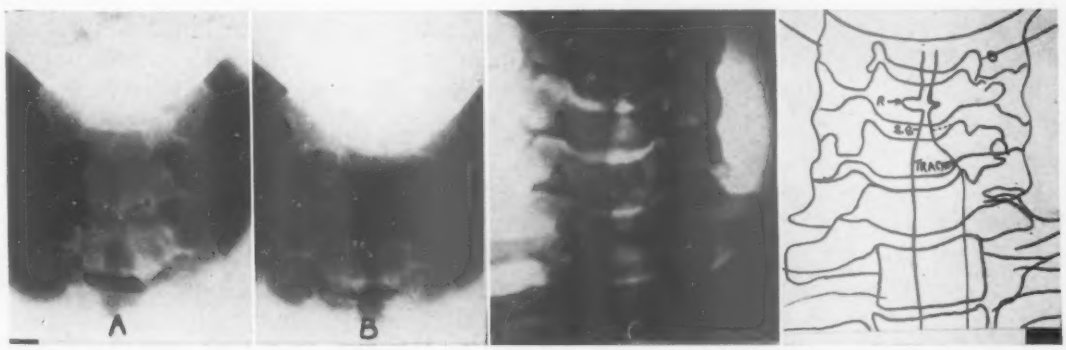


Fig. 7. Comparison of roentgen appearance of larynx in early carcinoma of true cord (*A* and *B*) with that of recurrent laryngeal nerve paralysis (*C*). *A*, *during phonation* airway is deviated toward involved side; infiltrated true cord, *TC*, is retracted and ventricle, *V*, is smaller on side of carcinoma. *B*, *with larynx at rest*, the fixed true cord, *TC*, is in same position as seen in *A*, while normal cord, *NC*, is abducted. *C*, recurrent laryngeal paralysis (roentgenoscopic appearance); ventricle is larger on side of paralysis, *R*, in contrast to small ventricle seen in *A*; arrows emphasize the difference in shape of lateral edges of airway in subglottic region on two sides.

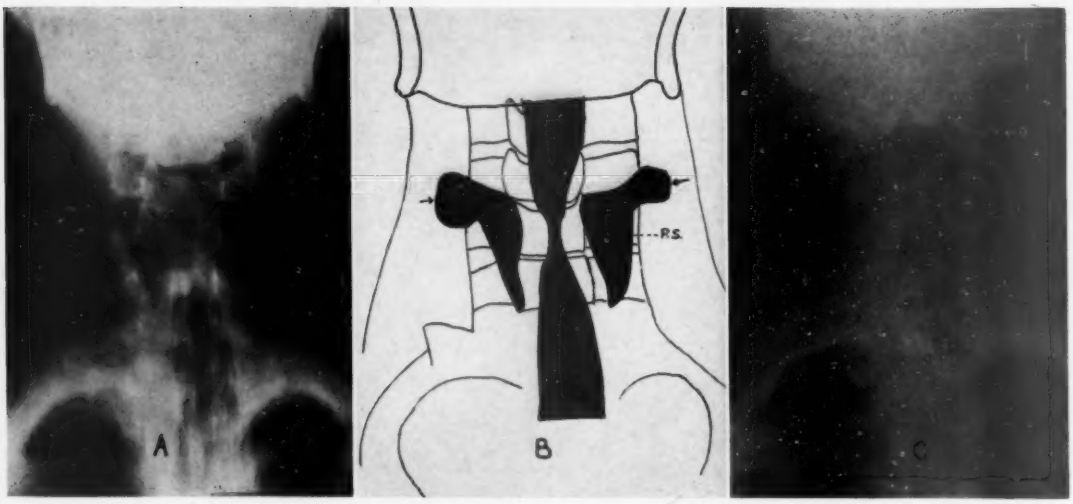


Fig. 8. Outpouching of the lateral pharyngeal walls that occur in some patients when the intrapharyngeal pressure is raised. *A*, arrows indicate lateral extremities of the ballooned-out tissues. *B*, tracing shows that these outpouchings represent the superolateral extremities of the pyriform sinuses, *PS*. *C*, spaces partially delineated by opaque solution at *B*.

is retracted from its usual midsagittal position (Fig. 7*A*). The roentgenogram exposed while the larynx is at rest indicates the lack of motion of the paralyzed or fixed true cord because this cord is in the same position as it was during phonation while the normal mobile cord changes its position from adduction to abduction (Fig. 7*B*).

It is sometimes possible to decide from roentgenoscopic and film examination whether lack of motion of one of the true cords is due to fixation by a malignant neoplasm or paralysis of the recurrent laryngeal nerve. A carcinoma nearly always obliterates or diminishes the size of the ventricle while if the cord is motionless due to nerve paralysis, the ventricle on the involved side may be larger than its fellow on the opposite side (Fig. 7*C*). In addition, a cord, if involved by tumor is increased in size, but, if paralyzed is not enlarged.

The importance of preliminary roentgenoscopy of the neck before film examination cannot be over-emphasized. This procedure should be carried out not only when there are symptoms referable to the neck, but also in all patients who are examined roentgenoscopically because it affords an opportunity to study the normal anatomy and physiology of the neck. The movements of the vocal cords during phonation and the action of the larynx, tongue, and muscles of deglutition during the swallowing act can be studied only during roentgenoscopy. It is necessary to determine by preliminary roentgenoscopy the proper position of the patient and phase of deglutition or phonation in order to obtain roentgenograms that yield maximum information.

Small outpocketings of the lateral pharyngeal walls are seen, in some patients, just above the laminae of the thyroid cartilage if roentgenoscopy is carried out with patient facing examiner during forced exhalation against closed lips and pinched nostrils (Fig. 8). Investigation in the anatomy dissecting room revealed that the lateral pharyngeal walls are unusually thin in these regions and this finding explains the ballooning of them when the intrapharyngeal pressure is raised. These outpouchings represent the superolateral extremities of the pyriform sinuses. My attention was called to the roentgen appearance of these normal spaces by Dr. W. E. Chamberlain.

The planigraph has been used in clinical medicine since 1931, but to date there are

only a few reports of its use as a diagnostic aid in the neck. Leborgne, in 1936, published the first anteroposterior planigraphic study of the larynx. The following year Canuyt and Gunsett, Greiner, Janker and Schneider reported their experiences with planigraphy of the larynx. In 1938, Regules and Caubarrere Leborgne, Huët and Péri, and others, contributed to the literature on this subject. Anyone interested in the principles of planigraphy and its clinical application is referred to the articles of Andrews, Baese, Bartelink, Bernard, Bocage, Chaoul, Frik, Grossmann, Kieffer, Moore, Ott, Pohl, Portes, Twining, Ballebona, Van der Plaats, Vogt, and Ziedses des Plantes.

At the present time we are using an apparatus which allows simultaneous longitudinal movements of the roentgen tube and the Potter-Bucky diaphragm in opposite directions in a straight line.* The tube and film move in horizontal planes which are therefore parallel to each other and to the plane of the body under examination. The tube tilts sufficiently during its travel so that the central beam is directed at the middle of the film throughout the exposure. With this equipment we are able to carry out anteroposterior planigraphic studies that demonstrate the larynx and adjacent structures exceptionally well (Fig. 9).

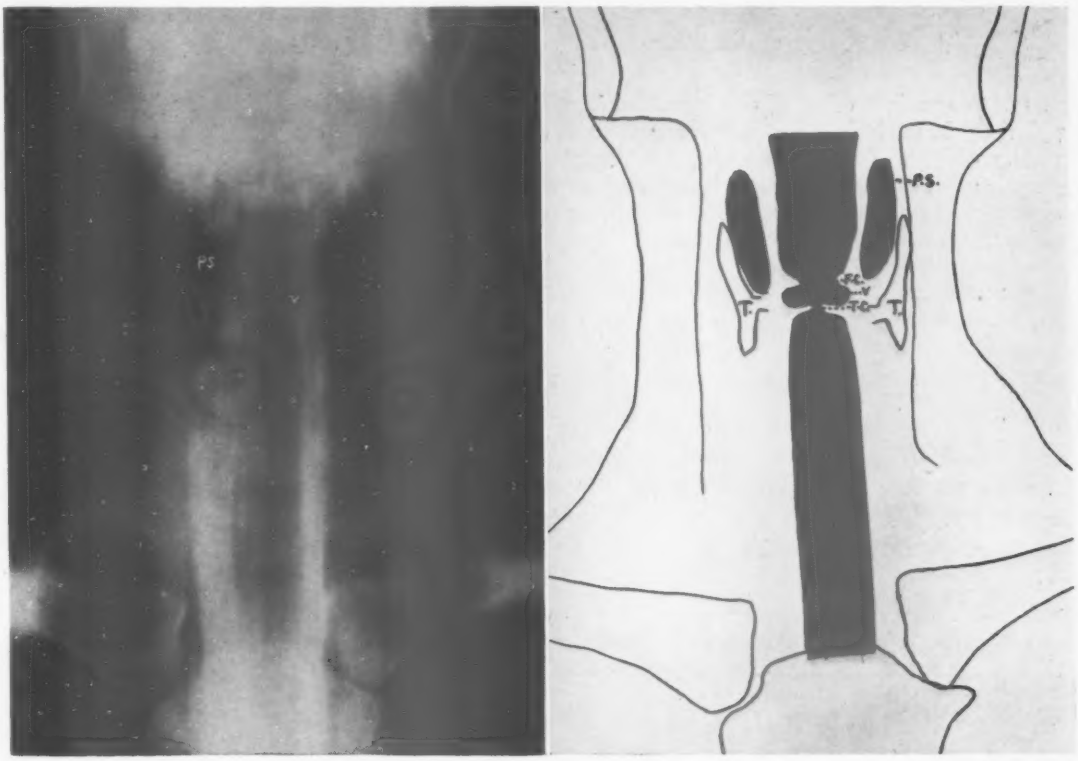


Fig. 9. Planigraphic roentgenogram of normal adult larynx. Note excellent definition of intrinsic laryngeal structures. *PS*, pyriform sinus; *FC*, false cord; *V*, ventricle; *TC*, true cord; *T*, thyroid cartilage.

It is well to keep in mind that success in demonstrating a lesion depends upon selection of the proper body section. We routinely take a lateral projection and measure the depth of the lesion before doing anteroposterior planigraphic studies. Even though the depth is predetermined by measurement, we feel that films should be exposed not only of the plane in which the lesion lies, but also in neighborhood

* For detailed description of a relatively simple method of adapting ordinary roentgen apparatus to planigraphy, see separate article in Department of Technique of this number.

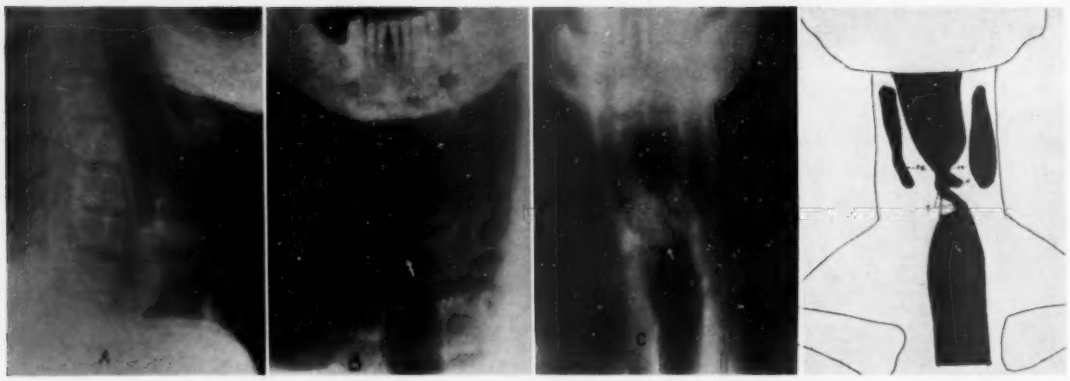


Fig. 10. Comparison of planigraphic and conventional roentgenograms in carcinoma of larynx. *A*, excess soft tissue in intrinsic larynx obliterates ventricle. *B*, arrow indicates true cord tumor lateralized by non-planigraphic film (ventral projection, but turned to facilitate comparison with *C*). *C*, anteroposterior planigraphic film delineates tortuous airway, encroachment on right pyriform sinus, obliterated right ventricle, and tumor of right true cord with subglottic extension (arrow). *PS*, narrowed pyriform sinus; *FC*, false cord; *V*, ventricle; *T*, tumor of true cord.

planes. We alter the depth of focus by 5 mm. steps and make exposures at four to five different levels.

Our experience indicates that planigraphic studies are valuable in the diagnosis of both benign and malignant lesions. Small discrete benign tumors, paralysis of the cords due to recurrent laryngeal nerve injury, and laryngocele are a few of the benign abnormalities that have been uncovered to date.

Planigraphic studies are especially useful when dealing with neoplasms of the larynx because the configuration of the mass and its relation to adjacent structures are better demonstrated in the coronal plane by planigraphy than by any other method (Fig. 10). Ventral projections, using a short target-film distance, lateralize a lesion, but it usually appears as a homogeneous mass, while planigraphic studies of the same region enable differentiation of the

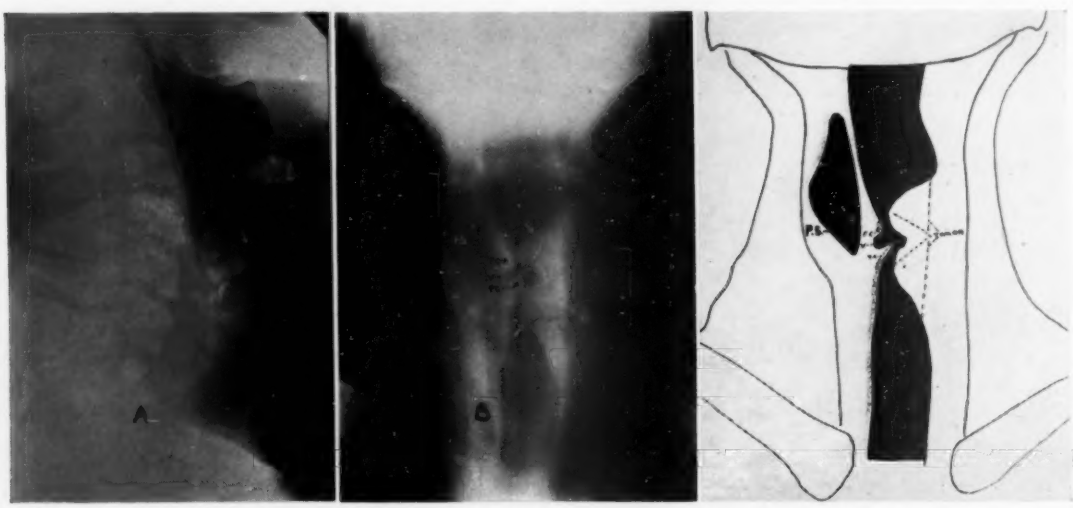


Fig. 11. Carcinoma of false and true cords on left with obliteration of left ventricle and pyriform sinus and subglottic extension. *A*, lateral roentgenogram shows no evidence of subglottic extension. *B*, planigraphic film indicates extent of neoplasm especially subglottic portion. *PS*, uninvolved pyriform sinus, opposite one obliterated by tumor; *FC*, normal false cord; *V*, normal ventricle; *TC*, true cord on uninvolved side. White arrows indicate margins of carcinoma of left false and true cords.

tumor from its surrounding structures. This special method is particularly valuable to uncover subglottic neoplasms and to delineate an airway that is narrowed by tumor (Fig. 11). Because planigraphic studies show so well the exact location and extent of a tumor, they are invaluable aids in deciding whether treatment should be by irradiation or surgery.

SUMMARY AND CONCLUSIONS

Roentgen examination of the neck using present day methods yields valuable information that was previously impossible to obtain. A method of obtaining ventral projections of the neck and larynx using a shock-proof roentgen tube and short target-film distance is described, and emphasis is placed on the value of this new technique to visualize normal laryngeal structures and to lateralize a lesion. Anteroposterior planigraphic studies show the outpocketing of each lateral pharyngeal wall that occurs in some patients when the intrapharyngeal pressure is raised as in forced exhalation against closed lips and pinched nostrils.

The planigraph is a valuable aid in the diagnosis and demonstration of laryngeal tumors, particularly if they extend into the subglottic region, and today examination cannot be considered complete unless the usual diagnostic procedures, including endoscopy, are supplemented by planigraphic studies. The roentgen appearance of a number of characteristic disease processes is discussed and illustrated.

REFERENCES

1. Andrews, J. R. Planigraphy. I. Introduction and history. Am. J. Roentgenol. & Rad. Therapy, 1936, *36*, 575–587.
2. Baclesse, F., and Leroux-Robert, J. Le rôle de l'examen radiologique dans le diagnostic des cancers sous-glottiques. *J. de radiol. et d'électrol.*, 1936, *20*, 645–656.
3. Baclesse, F., and Leroux-Robert, J. La radiographie des épithéliomas intra-larynges. *Ann. d'oto-laryng.*, 1937, 1100–1123.
4. Baese, C. Italian patent, 1915, and British patent No. 100.491, 1916–1917.
5. Baldenweck, L., and Gauillard, R. Recherches sur la radiographie normale et pathologique du larynx, *J. de radiol. et d'électrol.* 1933, *17*, 353–362.
6. Baldenweck, L., and Gauillard, R. La radiographie du larynx. *Paris méd.*, 1936, *1*, 93–98.
7. Barclay, A. E. Normal mechansim of swallowing. *Brit. J. Radiol.*, 1930, *3*, 534–546.
8. Bartelink, D. L. Roentgen section. *Nederl. tijdschr. v. geneesk.*, 1932, *76*, 23.
9. Bartelink, D. L. Method of obtaining clear pictures of a limited area by blocking out superfluous parts. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1933, *47*, 399–407.
10. Bartelink, D. L. Swiss patent No. 155930, 1932.
11. Belli, M., and Carnevale-Ricci, F. Sul valore diagnostico del-l'esame radiologico nella tuberculosi laringea. *Ann. di laring. otol.*, 1929, *30*, 61–71.
12. Bernard, E. Le diagnostic des lésions pulmonaires par la tomographie. *Mém. Acad. de chir.*, 1937, *63*, 446–451. Abs. *J. Am. M. Ass.*, 1937, *108*, 1982.
13. Bérard, L., and Boudènes, F. Données radiographiques dans le diagnostic des tumeurs laryngées et pharyngo-laryngées. *Lyon chir.*, 1936, *33*, 219–222.
14. Bérard, L., Ponthus, P., and Boudènes, G. Sur la technique et la valeur de la radiographie des tumeurs pharyngo-laryngées. *J. de radiol. et d'électrol.*, 1936, *20*, 331–343.
15. Bocage, A. E. M. French patent No. 536464, 1922.
16. Bouchet, M., and Huët, P. Essai de radiographie frontale du larynx. *Ann. d'oto-laryng.*, Feb., 1938, 103–112.
17. Brown, S., and Fine, A. X-ray study of neck. *Ohio State M. J.*, 1937, *33*, 626.
18. Brown, S., and Reinecke, H. G. Roentgenological study of the neck. Am. J. Roentgenol. & Rad. Therapy, 1928, *20*, 208.
19. Canuyt, G., and Gunsett. Tomographies frontales du larynx et des tumeurs laryngées. *Bull. Assoc. franç. p. l'étude du cancer*, 1937, *26*, 398–413.
20. Canuyt, G., and Gunsett. La méthode des coupes radiographiques. Tomographie ou planigraphie appliquée au cancer du larynx. *Presse méd.*, 1937, *45*, 1559–1561.
21. Celletti, L. La diagnosi radiologica delle affezoni del faringe. *Quaderni radiol.*, 1932, *3*, 89–91.
22. Chamberlain, W. E., and Young, B. R. Ossification (so-called "calcification") of normal laryngeal cartilages mistaken for foreign body, a correlation of roentgen and histologic findings. Am. J. Roentgenol. & Rad. Therapy, 1935, *33*, 441–449.
23. Chaoul, H. A new roentgenographic procedure in lung diagnosis; roentgenograms of sections of the lungs (tomography). *Deutsche med. Wchnschr.*, 1935, *61*, 700–703.

24. Chievitz, J. H. Untersuchungen über die Verknöcherung der menschlichen Kehlknorpel. *Arch. f. Anat. u. Entwcklngsgesch.*, 1882, 303–349.
25. Coutard, H., and Baclesse, F. Roentgen diagnosis during the course of roentgen therapy of epitheliomas of the larynx and hypopharynx. Am. J. Roentgenol. & Rad. Therapy, 1932, *28*, 293–312.
26. Ducuing, J., and Ducuing, L. Les tumeurs malignes de la corde vocale. *Rev. de laryng.*, 1936, *57*, 1085–1105.
27. Fraenkel, E. Über die Verknöcherung der menschlichen Kehlkopfs. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1908, *12*, 151–168.
28. Frik, K., and Ott, P. What are roentgenologic body section pictures able to accomplish at present? *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1934, *50*, 423–428.
29. Golden, R. Evaluation of roentgenology in otolaryngology; larynx. *Laryngoscope*, 1932, *42*, 915.
30. Grossmann, G. French patent No. 771.887, 1934.
31. Grossmann, G. Tomography I and II. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1935, *51*, 61–80; 191–209.
32. Grossmann, G. Lung tomography. *Brit. J. Radiol.*, 1935, *8*, 733–751.
33. Grossmann, G. Practical considerations of tomography. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1935, *52*, 44.
34. Hay, P. D. The Neck. A Roentgenological Study of the Soft Tissues, Consideration of the Normal and Pathological. *Ann. Roentgenol.*, Hoeber, New York, 1930.
35. Henckel, K. O. Sur la structure fonctionnelle des éléments cartilagineux du larynx. *Compt. rend. Soc. de biol.*, 1931, *108*, 648–649.
36. Hickey, P. M. Radiography of normal larynx. *Radiology*, 1928, *11*, 409.
37. Hickey, P. M. The Caldwell Lecture. Am. J. Roentgenol. & Rad. Therapy, 1931, *25*, 177.
38. Hirsch, I. S., and Baum, S. M. Roentgen diagnosis and treatment of laryngeal neoplasms. *Laryngoscope*, 1934, *44*, 144, and *Radiology*, 1935, *24*, 281.
39. Huët, P. C., and Péri, M. L'exploration radiologique des tumeurs de l'hypopharynx et du larynx. Les Impressions Boutin, Paris, 1938.
40. Iglauer, S. Value of roentgenography in diagnosis of disease of larynx and trachea. *J. Am. M. Ass.*, 1914, *63*, 1827–1831.
41. Jackson, C., and Jackson, C. L. The Larynx and its Diseases. W. B. Saunders Co., Philadelphia, 1937.
42. Jackson, C. L. Diagnosis of laryngeal disease; laryngoscopic appearances correlated with roentgenological observations. *J. Am. M. Ass.*, 1930, *95*, 1322.
43. Jönsson, G. A method for röntgen examination of the hypopharynx and upper passages. *Acta radiol.*, 1934, *15*, 125–128.
44. Kieffer, J., U. S. patent No. 1954321, 1929–1934.
45. Kieffer, J. The laminagraph and its variations. Am. J. Roentgenol. & Rad. Therapy, 1938, *39*, 497–513.
46. Leborgne, F. Nueva tecnica radiologica per cortes o secciones. *Anales del ateneo de clinica quirurgica*, July, 1936, 13–15.
47. Leborgne, F. Cáncer laríngeo y tomografía. J. Garcia Morales, Montevideo, 1938.
48. Ledoux-Lebard, R., and Djian, A. La radiographie du larynx de face. *Ann. d'oto-laryng.*, 1938, *6*, 567–574.
49. Le Maitre, L. Diagnostic radiologique du cancer du larynx. *Echo médical du Nord*, 1935, *1*, 1.
50. Mathey-Cornat, R. Contribution à l'étude du radio-diagnostic des tumeurs malignes du larynx et de l'hypopharynx. *Presse méd.*, 1934, *42*, 457.
51. McGehee, W. H. Epithelial polyp of larynx demonstrated by roentgen ray. *Radiology*, 1932, *19*, 60–61.
52. McGehee, W. H. Importance of the roentgen examination in polypoid tumors of the larynx. Am. J. Roentgenol. & Rad. Therapy, 1933, *30*, 464–467.
53. McNealy, R. W. Cystic tumors of neck; branchial and thyroglossal cysts, *S. Clin. North America*, 1933, *13*, 1083–1100.
54. Moore, S. Body section roentgenography with the laminagraph. Am. J. Roentgenol. & Rad. Therapy, 1938, *39*, 514–522.
55. Mosher, H. P. X-ray study of movements of tongue, epiglottis and hyoid bone in swallowing. *Laryngoscope*, 1927, *37*, 235.
56. Mulsow, J. E. Roentgenologic study of the hypopharynx, larynx and trachea. *Arch. Otolaryng.*, 1939, *29*, 326–333.
57. Ott, P. The present day accomplishments of body section visualization. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1935, *52*, 40–43.
58. Pack, G. T., and Craver, L. F. Tumors of larynx and thyroid; roentgenographic study. *Arch. Otolaryng.*, 1931, *13*, 658.
59. Pancoast, H. K. Roentgenology of the upper respiratory tract *J. Am. M. Ass.*, 1930, *95*, 1318–1321.
60. Pancoast, H. K. Roentgenographic anatomy and physiology of larynx and adjacent structures. *Arch. Otolaryng.*, 1931, *13*, 775–776.
61. Pendergrass, E. P. Value of roentgen diagnosis in diseases of neck and upper respiratory tract. *Arch. Otolaryng.*, 1931, *13*, 776–777.
62. Pfahler, G. E. New roentgenographic technic for study of thyroid. Am. J. Roentgenol. & Rad. Therapy, 1921, *8*, 81.

63. Pfahler, G. E. The roentgen diagnosis and treatment of carinoma of the larynx and pharynx. *Radiology*, 1939, *33*, 43–53.
64. Picchio, C. Appunti critici di anatomia radiografica e di semeiologia radiologica del collo. *Radiol. med.*, 1935, *22*, 881.
65. Pohl, E. Imperial German patent, No. 544200, 1927–1932, and Switzerland, No. 155613, 1930–1932.
66. Portes, F., and Chausse, M. French patent No. 541941, 1922.
67. Regules, P., and Caubarrere, N. L. Posibilidades radiograficas en el cancer de la laringe. J. Garcia Morales. Montevideo, 1938.
68. Sayama, M. Uber die Verknöcherung des Kehlkopfes bei Chinesen. *J. Orient. Med.*, 1931, *14*, 53.
69. Scheier, M. Weitere Mitteilungen über die Anwendung der Röntgenstrahlen in der Rhino- und Laryngologie. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1897, *1*, 59.
70. Scheier, M. Uber die Ossification des Kehlkopfs. *Arch. f. mikr. Anat. u. Entwick.*, 1902, *59*, 220.
71. Scheier, M. Zur Verknöcherung des menschlichen Kehlkopfes. *Berl. klin. Wchnschr.*, 1910, *47*, 1471.
72. Shannon, E. H., and Veitch, A. H. Diseases of the hypopharyngeal region producing dysphagia. A roentgenological consideration. Am. J. Roentgenol. & Rad. Therapy, 1939, *42*, 173–185.
73. Sussman, M. L. The value of roentgenologic examination of the neck. *Arch. Otolaryng.*, 1932, *15*, 371.
74. Taylor, H. K. and Nathanson, L. Roentgenologic study of tuberculosis of larynx and neck. Am. J. Roentgenol. & Rad. Therapy, 1934, *32*, 589.
75. Taylor, H. M. Ossification of cartilages of larynx and its relationship to some types of laryngeal diseases. *Ann. Otol., Rhin. & Laryng.*, 1935, *44*, 611.
76. Thost, A. La radiographie du larynx humain normal et pathologique. These, Hamburg, 1913.
77. Twining, E. W. Tomography, by means of a simple attachment to Potter-Bucky couch. *Brit. J. Radiol.*, 1937, *10*, 332–347.
78. Vallebona, A. A modified technique of roentgenographic dissociation of shadows applied to the study of the skull. *Radiol. med.*, 1930, *17*, 1090–1097.
79. Vallebona, A. Radiography with great enlargement (microradiography) and a technical method for the radiographic dissociation of the shadow. *Radiology*, 1931, *17*, 340–341.
80. Vallebona, A. A method of taking roentgenograms which makes it possible to eliminate shadows. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1933, *48*, 599–605.
81. Van der Plaats, G. J. So-called planigraphy with roentgen rays. *Nederl. tijdschr. v. geneesk.*, 1932, *76*, 1081–1085.
82. Van der Plaats, G. J. Some remarks on the system of planigraphy in x-ray work, x-ray research and development. N. V. Phillips Gloeilampenfabrieken, 182, Eindhoven, Netherlands, 1933.
83. Vogt, O. Short technical explanation of the tomograph for pictures of body sections. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1935, *52*, 44–46.
84. Waldeyer, A. Zur Individual- und Rassenanatomie des menschlichen Kehlkopfes. *Ztschr. f. Morphol. u. Anthrop.*, 1926, *26*, 68.
85. Wornig, B. Roentgen examination of laryngeal and hypopharyngeal tumors. *Acta radiol.* 1934, *15*, 8.
86. Young, B. R. Soft tissues of the air and food passages of the neck. Diagnostic Roentgenology. Ross Golden, Editor. Thomas Nelson and Sons, New York, 1938.
87. Ziedeses des Plantes, B. G. Planigraphic method in roentgenology. *Nederl. tijdschr. v. geneesk.*, 1932, *76*, 2796–2799.
88. Ziedses des Plantes, B. G. A new method of differentiation in roentgenography (planigraphy). *Acta radiol.*, 1932, *13*, 182–191.
89. Ziedses des Plantes, B. G. Planigraphy. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1933, *47*, 407–411.
90. Ziedses des Plantes, B. G. A method of obtaining separate pictures of definite parts of objects in roentgenograms. *Nederl. tijdschr. v. geneesk.*, 1934, *78*, 762–768.
91. Ziedses des Plantes, B. G. Planigraphy, a method of obtaining a clear image of an object at any desired plane. *J. de radiol. et d'électrol.*, 1934, *18*, 73–76.
92. Ziedses des Plantes, B. G. Planigraphy, a roentgenographic differentiation method (Thesis for doctorate degree). Kemink and Son N. V., Utrecht, Netherlands, 1934.

THE VALUE OF PROPER INTERPRETATION OF LIPIODOL BRONCHOGRAMS IN THORACIC SURGERY*

WITH A NOTE ON THE DISTRIBUTION OF BRONCHIECTASIS

By DAN W. MYERS, M.D., *and* BRIAN BLADES, M.D.
ST. LOUIS, MISSOURI

WHEN lipiodol was introduced by Sicard and Forestier[16] in 1922, it was possible for the first time to make an indubitable diagnosis of bronchiectasis and to demonstrate on roentgenograms the point of partial or complete bronchial obstruction resulting from endobronchial tumors. This accomplishment was of tremendous interest from the standpoint of making an accurate clinical diagnosis but did not materially alter the therapeutic methods at the time. Little attention was given to the detailed anatomy of the tracheobronchial tree and to the precise interpretation of lipiodol bronchograms until advances in thoracic surgery established lobectomy and pneumonectomy as the treatments of choice for bronchiectasis and bronchiogenic carcinoma. It is our purpose to discuss the diagnostic use of lipiodol in suppurative and neoplastic disease of the lung and to demonstrate the importance of accurate preoperative localization of pulmonary lesions in thoracic surgery.

TECHNIQUE OF BRONCHOGRAPHY

Various methods have been devised to accomplish the introduction of iodized oil. Although the method of endobronchial probing described by Goldman and Adams[7] appears to offer the advantage of permitting selective filling of any portion of the bronchial tree under direct roentgenographic control, we believe that the simplicity, rapidity, and relatively slight inconvenience to the patient of the supraglottic or aspiration method of Singer[14,17] will recommend it to the average physician. For more than ten years the supraglottic route has been utilized in this clinic with satisfactory results in 95 per cent of adults, the majority requiring no local anesthesia at all. Essential to the success of this method are: (1) the routine institution of postural drainage as an immediate preliminary to bronchography; (2) roentgenoscopic control during the instillation; (3) control of excessive cough by opiates (required only in the exceptional case), and (4) a thorough knowledge of the anatomy of the bronchial tree so that the patient may be properly positioned and the films properly interpreted. The use of roentgenoscopic control plus attention to the patient's position will permit the filling of any lobe, and will prevent the undesirable flooding of any particular area with an excess of oil.

ROENTGENOGRAPHY OF THE BRONCHIAL TREE

Lipiodol bronchograms made in the anteroposterior or posteroanterior projections result in a considerable superimposition of bronchial shadows. On the left, the lowermost divisions of the lingular bronchus, a branch of the upper lobe, terminate just above the level of the dome of the diaphragm, and there is usually considerable difficulty in differentiating lingula from lower lobe in the frontal plane projection. Figure 1, a lipiodol bronchogram of a patient with complete obstruction of the left lower lobe bronchus, demonstrates clearly the course and extent of the lingular bronchus and its branches. Similar confusion occurs in attempting to separate middle lobe from lower lobe divisions on the right when only the usual posteroanterior view is taken. The dorsal division bronchus

* From the Chest Service of Barnes Hospital and the Departments of Medicine and Surgery, Washington University School of Medicine, St. Louis.

to the right lower lobe, supplying that portion of lung referred to by Levitin and Brunn[9] as the superior division of the lower lobe, cannot be visualized in the frontal projection. It has been our custom to fill only one lung at a time with iodized oil, and to make roentgen exposures in both frontal and lateral positions. If the roentgenoscopic observation reveals that the lipiodol has entered both lungs, the lateral roentgenogram will be of no value, and roentgenograms must be taken in oblique positions. The right anterior oblique (left posterior oblique) will best visualize the branches of the left main bronchus, and the divisions of the right bronchial tree are most clearly separated in the left anterior oblique view. Since reading the excellent roentgen anatomic study of the oblique positions by Peirce and Stocking,[13] we have been employing the oblique projections more frequently, because these are the only positions which permit clear separation and identification of the secondary bronchial divisions.

Fig. 1. Obstruction of left lower lobe bronchus by bronchiogenic carcinoma. Lipiodol film demonstrating course and extent of branches of left upper lobe bronchus as visualized in posteroanterior projection. Point of bronchial obstruction shown by arrow.

BRONCHIECTASIS

Refinements in the technique of thoracic surgery during the past decade have established lobectomy or pneumonectomy as the ideal treatment for bronchiectasis. Dramatically successful though these procedures may be, they place a heavy responsibility on the physician and surgeon recommending them. Bronchiectasis can be cured only by the extirpation of all the involved tissue and, since it is often impossible to be certain of the extent of the disease during operation, it is imperative to determine its exact location as a preliminary to surgery. Failure to remove all the bronchial dilatations results in a failure to cure the disease, producing at best an amelioration of the symptoms. Physical examination is notoriously unreliable in revealing the extent of the lesion; signs may be entirely lacking except in the most grossly involved areas. Routine roentgen films are equally ineffectual in localizing the bronchial dilatations. Bronchoscopy, which is part of the routine study of our patients with bronchiectasis, may aid in localization through demonstration of the source of sputum, and may reveal a bronchial obstruction as the etiologic factor productive of the disease. By far the most reliable method of determining the extent of bronchiectasis consists, however, in mapping out the entire bronchial tree by means of radiopaque oil.

A report of the cases of bronchiectasis observed at Barnes Hospital[2] prior to 1930 referred to bronchiectasis as essentially a disease of the lower lobe. Upper or middle lobe involvement was diagnosed in only 15 of the 149 reported cases, an incidence of 10 per cent. These statistics are no longer tenable in the light of more recent observations. In discussing 49 cases subjected to lobectomy, Churchill[4] mentioned the location of the bronchiectasis in 24, and in 8 instances (33 per cent) involvement of either the lingula of the left upper lobe or of the right middle lobe was present. In reporting 15 lobectomies for bronchiectasis, O'Brien[12] stated that 4 of the 11 cases

Fig. 2. Left anterior oblique view of a patient with bronchiectasis of right lower and middle lobes. Arrow points to middle lobe.

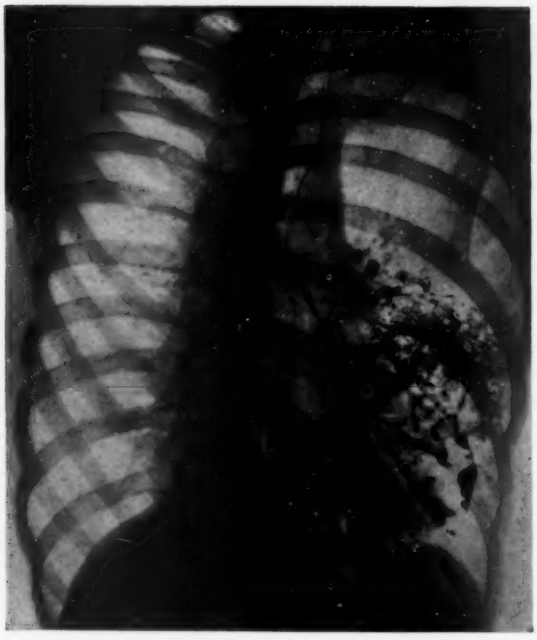


Fig. 3. Right anterior oblique film demonstrating bronchiectasis of left lower and lingular division of upper lobe.

of unilateral disease showed dilatations in either middle or upper lobe.

During the past two years, in a study of potentially surgical cases of bronchiectasis, we have found an astonishingly frequent involvement of the lingular division of the left upper lobe and of the right middle lobe in association with bronchiectasis of the lower lobe on the corresponding side (Figs. 2 and 3). The distribution of bronchial dilatations in the patients observed is presented in Table 1. The statistics quoted do not include those cases of bronchiectasis which apparently developed as a sequel to long standing asthma or in-

Table I

Distribution of bronchiectasis in 66 cases

Single lower lobe		20
right lower lobe	7	
left lower lobe	13	
Two lobes on the same side		27
right lower and middle lobes	10	
left lower and lingular division of upper lobe	17	
Single lobe other than lower lobe		5
right middle lobe	4	
left upper lobe	1	
Universal		5
entire right side	1	
entire left side	4	
Bilateral		9
3 bilateral lower lobes	3	
3 bilateral with more than lower lobes involved	6	
Total		66

stances of dilatations occurring in elderly patients in association with chronic cough and emphysema. Furthermore, bronchiectasis secondary to bronchiogenic carcinoma, lung abscess, and pulmonary tuberculosis are excluded, for in these cases the incidence of location of the dilatations and the surgical problems presented are usually those of the primary disease.

Before deciding upon a major surgical procedure as a treatment for bronchiectasis, it is essential to visualize every bronchial division in both lungs by means of roentgenographic studies following intrabronchial instillations of an iodized oil contrast medium. Until the bronchial tree has been completely visualized, one is not justified in assuming that the bronchial dilatations are confined to one or two lobes. Thick secretions may partially block a bronchus and prevent filling of bronchiec-

tatic areas, as illustrated in Figure 4. Repetition of bronchography after postural drainage or introduction of lipiodol by the bronchoscopic route should be attempted. It has been our practice to attempt the filling of only one side of the bronchial tree on any one day, and if complete visualization cannot be thus accomplished, a different technique for introducing the lipiodol should be tried. The proper oblique view is the most essential, and in most instances will suffice. In some cases roentgenograms in frontal and lateral projections are also desirable.

LUNG ABSCESS AND PSEUDO-ABSCESS

In our experience non-tuberculous abscesses of the lung can rarely be filled with lipiodol given by the supraglottic method. Hickey and Furstenberg[8] reported this same difficulty in 1926 and attributed it to swelling of the mucosa of the bronchus leading to the abscess. Bronchoscopy with aspiration of secretion preceding instillation of the oil is more often successful in demonstrating the cavity.

Although the bronchogram does not demonstrate the actual cavity, it may nevertheless be of considerable value in localizing the position of the lesion. Although the bronchus leading to the abscess is ordinarily blocked, one can derive or deduce the position of the lesion and its relationship to the chest wall by determining the identity of the obstructed bronchial division. Each bronchus has a corresponding pulmonary segment,[6,11] so that if the involved bronchial division is identified from a study of the posteroanterior and lateral roentgenograms, the precise localization of the abscess is facilitated.

Bronchography is of prognostic value in chronic abscess of the lung. The longer the duration of the abscess, the greater is the likelihood of development of secondary bronchiectasis. The coexistence of bronchiectasis and lung abscess, recognizable only when iodized oil is employed, renders complete symptomatic cure following simple surgical drainage less likely, and the possibility that lobectomy may eventually be required is at once suggested. Figure 5 demonstrates a residual bronchiectasis in a patient who has previously undergone operation for drainage of a chronic pulmonary abscess.

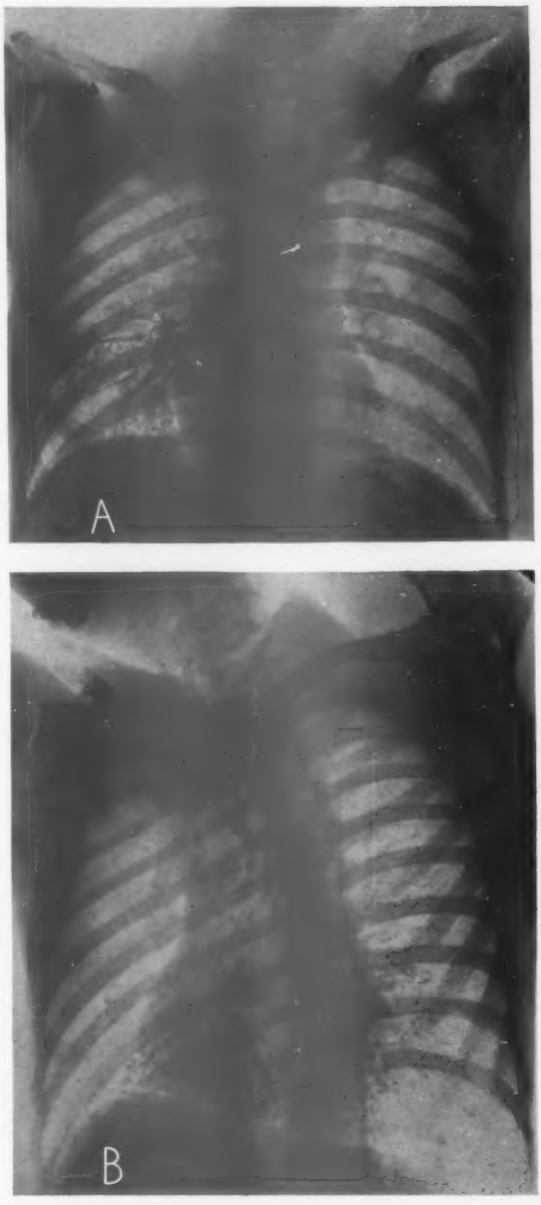


Fig. 4. *A*, incomplete filling of lower lobe due to the presence of secretion, no abnormality shown. *B*, same patient two days later, bronchography performed after postural drainage demonstrating large bronchiectatic pockets. Film taken in left anterior oblique position.

In those patients with cystic disease of the lung, a cyst may become infected and

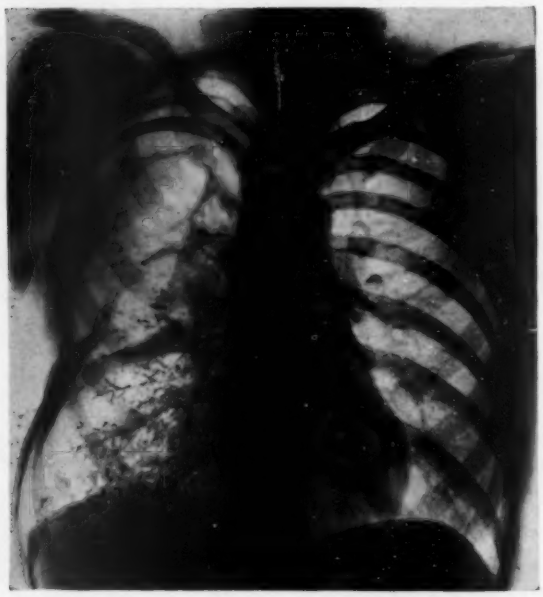


Fig. 5. Residual bronchiectasis in a patient who has had operation for drainage of lung abscess. Lipiodol injected through sinus in chest wall.

simulate an ordinary lung abscess in its roentgenographic appearance. Figure 6 depicts such a case. The patient had been given pneumothorax treatment elsewhere for abscess of the lung. Injection of lipiodol through the chest wall into the presumed pneumothorax pocket demonstrated the

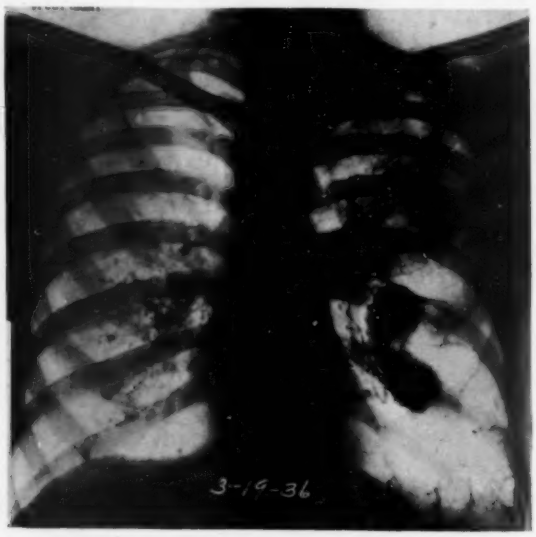


Fig. 6. Cystic disease of lung. Note the trabeculae outlined by lipiodol injected through the intact chest wall with syringe and needle.

presence of multiple trabeculae in this large air space, which was in fact an area of pulmonary cystic disease.

Flooding of the alveoli with excess of iodized oil or "drowned lung," as it is sometimes called, presents an appearance suggestive of a cavity in the lung. Emile Sergent[15] first commented upon this phenomenon as a possible source of error in the use of lipiodol, and shortly afterward the similarity in appearance of "drowned lung" and oil filled cavity was reported in this

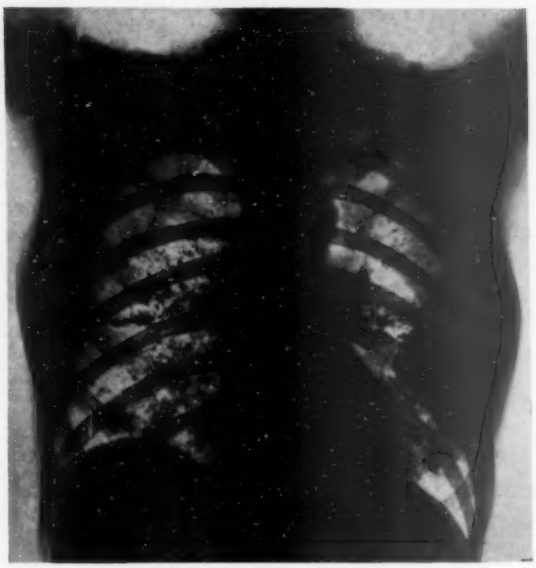


Fig. 7. Dense shadow in left axillary region resulting from flooding of the alveoli with iodized oil.

country.[5,18] The work of Mosher[10] on dogs proved quite conclusively that alveolar flooding was not a pathological occurrence. Figure 7 shows the opaque shadow resulting from the entry of an excess of oil into one terminal bronchus. Roentgenoscopic control during instillation of lipiodol will largely eliminate this phenomenon, for the position of the patient should be changed when the bulk of the contrast medium is seen to gravitate toward one minor bronchial division. According to the expressed views of Bendove and Gershwin,[3] with which we are in agreement, the alveolar filling is in itself an indication that the bronchus leading to the flooded sector of the lung is normal.

INTRABRONCHIAL AND INTRATHORACIC TUMORS

Bronchography obviously cannot displace bronchoscopy in the diagnosis of bronchial stenosis, for the iodized oil merely shows the existence of a block without offering any evidence as to the etiologic factor. The use of lipiodol, however, as a preliminary to bronchoscopy often gives the operator valuable information, suggesting which bronchus should be most thoroughly explored. In cases where bronchial block may be suspected, lipiodol studies alone may be sufficient to rule out such a possibility, but it is always hazardous to exclude completely an intrabronchial neoplasm without bronchoscopy. Occasionally exudate in the air passages may obstruct the descent of lipiodol and give the appearance of a true bronchial stenosis in the roentgenogram. Such pseudostenoses are much less frequent if postural drainage is instituted as a preliminary to bronchography.

Although lipiodol bronchograms give important information concerning the location of bronchiogenic carcinomas situated in the major bronchial divisions, measurements from the carina to the point of obstruction as seen on the roentgenogram cannot be relied upon to determine operability. In the majority of instances, subsequent bronchoscopy and examination of the specimen following operation establish the position of the tumor proximal to that anticipated from the bronchograms.

Occasionally it is difficult or impossible to determine whether a lesion is intra- or extrapulmonary by ordinary roentgenograms. Figure 8 shows the apex of the lung, which is well filled with lipiodol, displaced downward by a mediastinal tumor. The bronchogram established the presence of the extrapulmonary tumor which was later successfully removed.

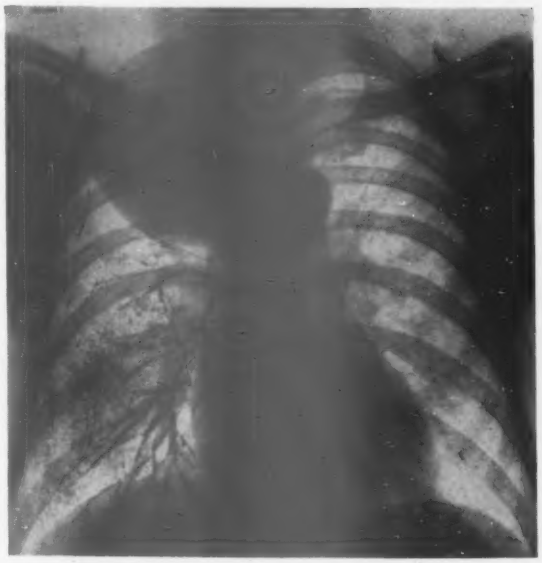


Fig. 8. Mediastinal tumor which has pushed apex of lung downward. Lipiodol filling shows that tumor is extrapulmonary.

SUMMARY

The value of iodized oil in the investigation of certain surgical diseases of the chest is discussed. Lipiodol roentgenograms constitute an indispensable part of the study of bronchiectasis. In 57 per cent of the cases with left lower lobe bronchiectasis the lingula of the left upper lobe was also diseased. Right middle lobe involvement was demonstrated in 59 per cent of right lower lobe bronchiectasis. The importance of a thorough knowledge of the roentgen anatomy of the bronchial tree and the advantage of oblique and lateral positions in depiction of the bronchi are pointed out. The technique of bronchography by the supraglottic method is briefly considered with mention of certain precautions to avoid the diagnostic pitfalls of pseudoblock and drowned lung. Information of diagnostic and prognostic value may sometimes be obtained in pulmonary abscesses and intrathoracic neoplasms.

REFERENCES

1. Ballon, D. H. Lipiodol in diagnosis of bronchopulmonary lesions by bronchoscopic method; report of fifty cases. *Arch. Otolaryng.*, 1926, *3*, 403–422.
2. Ballon, H., Singer, J. J., and Graham, E. A. Bronchiectasis. *J. Thoracic Surg.*, 1932, *1*, 502–561.
3. Bendove, R. A., and Gershwin, B. S. Inverse ratio in roentgen visualization of bronchi and

alveoli after injection of contrast media. Am. J. Roentgenol. &. Rad. Therapy, 1934, *31*, 323–327.

4. Churchill, E. D. Lobectomy and pneumonectomy in bronchiectasis and cystic disease. *J. Thoracic Surg.*, 1937, *6*, 286–311.
5. Furstenberg, A. C., and Hickey, P. M. Demonstration of lower air passages by intratracheal injection of lipiodol. *Tr. Am. Laryng., Rhin. & Otol. Soc.*, 1926, pp. 4–10.
6. Glass, A. Bronchopulmonary segment with special reference to putrid lung abscess; anatomic and roentgenographic aspects. Am. J Roentgenol. &. Rad. Therapy, 1934, *31*, 328–332.
7. Goldman, A., and Adams, R. Endobronchial probing combined with serial selective bronchography fluoroscopically controlled. *Ann. Surg.*, 1937, *106*, 976–991.
8. Hickey, P. M., and Furstenberg, A. C. Roentgenographic demonstration of trachea and bronchi. Am. J. Roentgenol. & Rad. Therapy, 1926, *15*, 227–230.
9. Levitin, J., and Brunn, H. Study of lower lobe of lung; explanation of roentgenologic shadows. *Arch. Int. Med.*, 1936, *57*, 649–665.
10. Mosher, H. P. False lung abscess and lipiodol. *Laryngoscope*, 1927, *37*, 138.
11. Neil, J. H. Gilmour, W., and Gwynne, F. J. Broncho-pulmonary segments; radiological, pathological and bronchoscopic considerations, with special reference to subapical broncho-pulmonary segment. *M. J. Australia*, 1937, *2*, 165–172.
12. O'Brien, E. J. Results of fifteen consecutive one-stage lobectomies for bronchiectasis. *J. Thoracic Surg.*, 1937, *6*, 278–285.
13. Peirce, C. B., and Stocking, B. W. Oblique projection of thorax; anatomic and roentgenologic study. Am. J. Roentgenol. & Rad. Therapy, 1937, *38*, 245–267.
14. Pritchard, S., Whyte B., and Gordon, J. K. M. Use of iodized oil in diagnosis and treatment of bronchial affections. *J. Am. M. Ass.*, 1926, *86*, 1119–1123.
15. Sergent, E. (Discussion, Armand-Delille, P. F.) Contribution a l'étude des dilatations bronchique chez l'enfant au moyen des injections intratracheales de lipiodol. *Bull. et mém. Soc. méd. d. hôp. de Paris*, 1924, *48*, 344–346.
16. Sicard, J. A., and Forestier, J. Méthode générale d'exploration radiologique par l'huile iodée (lipiodol). *Bull. et mém. Soc. méd. de chir. de Paris*, 1922, *46*, 463–469.
17. Singer, J. J. Simple method of introducing iodized oil into lungs. *J. Am. M. Ass.*, 1926, *87*, 1298.
18. Smyth, D. C., and Schall, L. A. Pneumography by lipiodol; its present uses and limitations. *Boston M. & S. J.*, 1927, *197*, 891–915.

Vol. 44, No. 4

A ROENTGENOLOGICAL STUDY OF CYSTINE URINARY CALCULI

By HARVEY R. MORRISON, M.D.
Department of Roentgenology of the Massachusetts General Hospital
BOSTON, MASSACHUSETTS

1. HISTORICAL

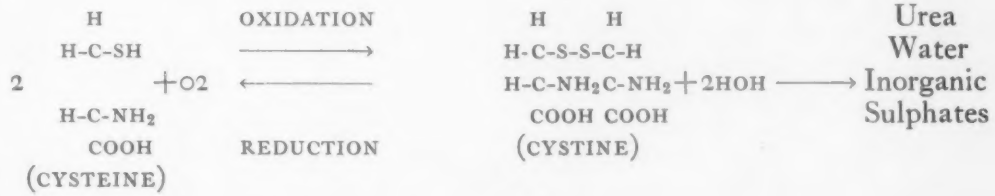
CYSTINURIA and cystine stones are by no means new to medical literature. In 1810, Wollaston, before the Royal Society of London, presented a paper, "On Cystic Oxide, a New Species of Urinary Calculus," deriving the name from "kystis" meaning bladder, and reported 2 cases of bladder stone. In 1822, Berzelius proposed the name cystine for the substance as it had been proved not to be an oxide. Civale, in 1838, commented that while this corrected an error in chemistry, it perpetuated an error in physiology since cystine is excreted by the kidneys and does not originate in the bladder. In 1824, Stomeyer and Prout observed the characteristic hexagonal crystals upon which the diagnosis is based, reporting a case of cystinuria with bladder stone. Thaulow, in 1838, worked out the chemical formula for these crystals. In 1840, Prout reported the hereditary character of cystinuria. Cantanini, in 1881, and Beale, in 1884, successfully treated cases of cystine stone by alkalinization with ammonium carbonate. As early as 1900, Simon reviewed the literature and was able to gather 102 cases of cystine stones. Spiegal, in 1901, proved cystine to be an intermediary product in protein metabolism. Rumpel, in 1903, is credited with having first demonstrated cystine calculi roentgenologically. Kretschmer, in 1916, collected 107 cases of cystine stones from the literature and published an excellent bibliography of over 140 references.

In spite of the mass of literature published on this subject since the turn of the century, slight attention has been paid it in the American roentgenological journals and textbooks. The purpose of this paper is to summarize briefly what is known about the subject and to clarify it in one regard. There has been much discussion concerning the radiopacity or non-opacity of these calculi. The erroneous impression that they are visualized with difficulty has been established and this I hope to correct.

2. DESCRIPTION

Cystinuria, according to Garrod, is an anomaly of the intermediary protein metabolism in which cystine, escaping its usual prompt destruction, appears in the urine and occasionally is deposited as calculi in the urinary tract. Its precursor, *cysteine*, is produced in cell metabolism and exists in all parenchymatous organs and body fluids. In normal metabolism the nitrogenous portion is usually excreted as inorganic urea and the sulphur-containing portion is usually excreted as inorganic sulphate. Cystine is the main sulphur-bearing amino-acid, containing approximately 26 per cent sulphur, and is one of the "essential" amino-acids as well.

Cystine crystals, as observed in the urine, are hexagonal, highly refractive plaques soluble in alkalies, inorganic acids and ammonia, but insoluble in water, acetic acid, alcohol and ether. Alsburg and Folin showed that although this amino-acid in

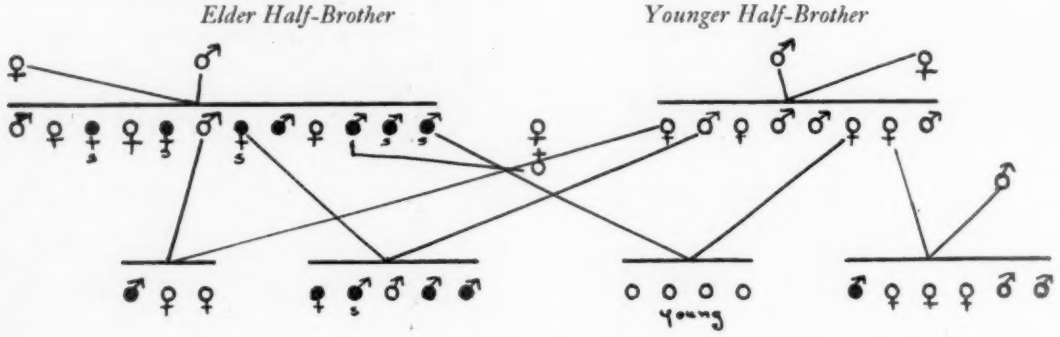


the body is both exogenous and endogenous, in cystinurics the cystine excreted is proportional to the protein intake although a reduction in the latter does not eliminate its output altogether. Cystine is found in largest amounts in the protein, lactalbumin. Normally, up to 4.5 mg. per cent of cystine can appear in solution in the urine, but when this is exceeded, cystine as crystals appears. Cystine in large amounts is toxic. Lignac and Abderhalden have reported autopsied cases in children with cystinuria and severe metabolic disturbances whose organs and skin contained cystine crystal deposits.

Cystine calculi may be of any size or shape ranging from grains of sand to smooth round or oval stones or even to staghorn proportions. They are never laminated unless mixed with inorganic salts. (Renander reports a laminated stone due to protein matrix.) The pure calculi appear as a mass of confused, yellow-brown crystals simulating maple sugar, waxy to the touch, with an occasional yellow-green cast. They may be facetted and not infrequently cystine may be only one component of a mixed stone. According to Jaches and Sussman, cystine stones do not originate in the cortex but in the calyces where they are at first smooth and occasionally found adherent to the mucosa. The explanation for the formation of cystine calculi is far from satisfactory and is left at best with the theory of crystallization of a supersaturated solution. Infection has been indicted but the large majority of cases have sterile urines before instrumentation.

3. HEREDITY

The hereditary character of cystinuria was first enunciated by Prout in 1840. Since then it has been confirmed by many investigators among whom are Macalpine, Kretschmer, Cohn, Strasser and Thin. A chart of Thin's cystinuric family is appended.



♂ ♀ Male and female

♂ ♀ Male and female Cystinuric

s s Stone former

4. INCIDENCE

The incidence of cystinuria and of cystine lithiasis in the population at large is probably much greater than any estimates up to the present time would tend to show. In special studies of large groups of urines, Simon found one cystinuric in 15,000 urines; Primavera, one in 20,000 urines;

and Sondern, 4 in 35,000 urines. Lewis, using the Sullivan chemical test checked by crystal study in positive instances, examined the urines of 10,534 college students in Michigan, 6,253 males and 4,281 females. Three males and one female, or 0.037 per cent, had positive chemical and crystal tests. If the 14 having strongly positive chemical tests and the 11 having weakly positive chemical tests in absence of positive crystal findings are added to the group above, the percentage is only 0.27 per cent. None of these cases had stones and only one had a known cystinuric relative and she was a stone former. Cystinuria is obviously a rare condition.

Very few cystinurics form stones and here again accurate statistics are not to be had. Cystinuria has been diagnosed almost exclusively in connection with the presence of calculi in patient and relatives. Therefore, a true basis for estimate is lacking. The probability of stone formation in cystinurics has been estimated to range from 0.26 to 2.5 per cent, the latter being nearer the accepted figure although it is undoubtedly too high. Morris found 2 stones in 77 cystinurics and Mörner (1921) found 47 stone formers in 5,292 cystinurics, 2.6 per cent and 0.88 per cent, respectively. Mörner (1936) collected 36 cases of cystinuria in Sweden, 22, or 72.2 per cent, having stones.

The relative frequency of cystine stones compared to other stones is reported by Nakano as 1.1 per cent. He found 7 cystine stones in 600 urinary calculi. Sum-Schick reports the figures of the following authors: Larry 0.63 per cent, D'Etoile 0.54 per cent and Benike 0.46 per cent. One per cent is the usually accepted figure.

Cystine lithiasis is preponderantly a male disorder, 70 to 80 per cent of the cases being in males. It is also considered a disease of childhood, 25 per cent being in young children. However, Renander, reviewing 32 cases of cystinuria reported in Sweden, 26 being stone formers, found that in 18 of the latter about whom he had complete data, 11 occurred over the age of twenty-five years and one case had had his first stone at sixty-seven years of age. The youngest patient reported is ten and a half months, the eldest, eighty-one years.

Calculi may be unilateral although they are usually bilateral, transient or more usually persistent throughout life, and renal or ureteral more than vesicle when discovered.

The formation of stones may be quite rapid as evidenced by a case reported by Renander who found a bean-sized stone five months after a negative roentgen examination. Stein found a stone filling the whole pelvis three weeks postoperatively. Braasch and others maintain that the average time of recurrence of stones in general is two years. He also states that the incidence of recurrence is 2.75 per cent but this seems much too low when considering cystine stones.

5. CLINICAL DIAGNOSIS

Cystinuric patients are for the most part healthy individuals and remain so even after their stone-forming activities commence. The history of passing showers of stones over a long period of time is significant and typical, especially in the younger age groups. Since cystine calculi can lodge anywhere in the urinary tract—urethra, bladder, ureter, kidney pelvis or possibly in the renal parenchyma (although the latter possibility is denied by most authorities)—their location, therefore, determines the symptomatology.

The first symptom is usually renal or ureteral colic. If the calculi are not being passed, and particularly if there is a large solitary staghorn calculus in the renal pelvis, the patient may complain of a heaviness or a dull ache in the flank accompanied by malaise. The symptoms may be transitory and the patient become free for life, or they may persist as is more usual. The symptoms may be unilateral or more usually bilateral. Hematuria is said to be out of proportion to the amount of difficulty encountered with the stones. The decomposing urine gives off a foul odor of hydrogen sulphide. Concomitant urinary

infections in the absence of instrumentation are rare.

The finding of cystine crystals in the urine of a stone former is only presumptive evidence that the stone is cystine. Chemical analysis of the stone alone will determine the degree of purity of the cystine calculus since mixed stones and even stones other than cystine are not uncommon in cystinurics.

6. TREATMENT

There are definite indications for the treatment of cystine calculi. Cystine is known to be soluble in alkalies. Sodium bicarbonate, sodium citrate or ammonium carbonate taken by mouth in such quantities that the urine remains constantly alkaline to litmus is reported to cause dissolution of stones present in the renal pelvis and to prevent the formation of further stones. This therapy may be augmented by the prescription of a minimum protein diet consistent with the metabolic needs of the patient's age and the avoidance of foods rich in cystine.

Fluids should be forced up to 2–3 liters daily to maintain the cystine concentration in the urine below the point at which it is thought the supersaturated solution of cystine will precipitate and crystallize as calculi. Lavage of the renal pelvis with mercurochrome or other alkalies has been advocated (Crowell). Serum therapy as well as vaccines has been tried but not generally accepted.

Concomitant urinary infections must be dealt with appropriately. Surgical intervention for the removal of calculi from the renal pelvis to prevent further kidney damage and to remove calculi impacted in the ureters, bladder or urethra is resorted to when indicated.

Concerning the results of alkalinization, authorities differ. Stallman, Crowell, Kamil, and Reaves report excellent results, with the roentgen disappearance of renal stones. Patch, Jacoby and others have failed to have success. Harris believes that alkalinization prevents recurrence. Possibly this latter observation is the most constant value of the combined treatment. Many observers caution that the use of alkalies leads to the production of those stones best formed in alkaline medium.

7. DIFFERENTIAL DIAGNOSIS

From other types of stones: This may not be always possible, particularly from a roentgenological point of view, but should be borne in mind. The history of frequent passage of stones in an otherwise healthy young person is suggestive. The finding of cystine crystals in the urine and the analysis of the calculi make the diagnosis certain. The roentgenological aspects of the diagnosis will be discussed later.

From appendicitis: The diagnosis may be confused when attacks of colic or a single attack of colic occur in the absence of clear-cut physical signs and urinary findings. The routine flat abdominal film is not always a sufficient method for the exclusion of calculi since a small calculus, particularly if it lies in the ureter, may not be visualized due to poor preparation, faulty technique or confusing shadows. It is of interest to note in the reported cases and among our own cases how many negative appendices have been removed before the correct diagnosis was made.

From pyelitis: The passage of stones in the absence of roentgen examination and even the presence of renal calculi may cause such mild symptoms that a renal infection with poor drainage is suspected.

8. LAWS GOVERNING THE RADIOPACITIES OF SUBSTANCES

The intensity of roentgen rays decreases in an exponential curve with passage through each centimeter of substance. The amount of decrease depends on the wave length of the beam, the shorter the wave length the less the absorption, and on the atomic weight of the substance, the higher in the periodic table the substance is found the more the absorption. Secondary production is greater with the shorter wave lengths.

The specific radiopacity of a substance is directly proportional to its specific gravity and also increases with the atomic weight directly as in the periodic table. Arcelin states that not only the atomic weight but also the physical state of the substance must be considered, whether it is a gas, liquid or solid and whether the latter is amorphous, loosely or compactly crystalline. The molecular concentration is therefore important and applicable to the study of calculi: A porous calculus will cast a lesser shadow than a dense, compact one of the same substance.

White arranges the more common stones according to their molecular weights as follows: 1. Ammonium urate. 2. Uric acid. 3. Sodium urate. 4. Magnesium urate. 5. Potassium urate. 6. *Cystine*. 7. Calcium oxalate. 8. Calcium carbonate. 9. Calcium phosphate. This order of arrangements has been borne out experimentally by Arcelin, Pflaumer, Schinz, Telemann and White employing various methods with minor disagreements which, however, do not affect the relation of cystine to the other calculi.

Table I

RESULTS OF EXPERIMENTS SHOWING THE RELATIVE DENSITIES OF URINARY CALCULI TO THE ROENTGEN RAY

Atomic Weight	Arcelin Experiment	Winsbury-White Experiment	Telemann Experiment	Renander Experiment	Pflaumer Experiment	Schinz Experiment
Xanthine		Uric acid	1.0		0.018	1.2
Uric acid	Uric acid	Xanthine	0.97		0.019	
Water and body tissue			1.0 1.0	1.0 1.0	0.026	1.0
Na, K, Ca and Mg urates	Mg and Ca urates, triple phosphates, xanthine	Triple phosphates, mixed urates			0.035 (Na urate) 0.09	1.38
Cystine	*Cystine*	*Cystine*	1.18	3.5 to 4.4	0.07	3.7
Ammonium magnesium phosphate			1.2			4.1
Calcium oxalate	Calcium oxalate	Calcium oxalate	1.36		0.15	10.8
Calcium carbonate			1.33		0.19	15.0
Calcium phosphate	Calcium phosphate	Calcium phosphate	1.25		0.16	22.0

These facts have been compiled in Table 1 to demonstrate that cystine is more radiopaque than all other stones except those containing calcium, phosphorus and magnesium.

An attempt to apply these dicta to our problem reveals another important factor involved in the visualization of calculi. In addition to the specific radiopacity of the calculi, the specific radiopacity of the body

tissues in which they lie must be considered. The body tissues are composed of low molecular weight substances approaching water in density. A calculus to be visualized must be denser than these surrounding substances. All urinary calculi will cast a shadow when surrounded by air. A density differential or contrast between body tissue and stone must be established. In the obese patient this is a real problem.

The radiopacity of a calculus within the body cavity is determined, therefore, by (1) the nature of its constituents (atomic weights); (2) its structure (density); (3) its thickness; and (4) the density differential between it and the tissues in which it rests.

9. ROENTGENOGRAPHIC TECHNIQUE

Most authors have stressed the importance of taking as nearly perfect roentgenograms as possible in order to raise the average of stones visualized. This recommendation is particularly valid in the diagnosis of ureteral stones. Pflaumer reports that 16 per cent of urinary calculi are overlooked. Peterson from this clinic reported 4 per cent undiagnosed and found this to be an average figure in the literature.

From the above discussion the important principles in stone roentgenography are to increase the contrast between stone and tissues to the maximum and to avoid extraneous factors interfering with their visualization. The following suggestions are offered for roentgenograms taken to diagnose urinary calculi:

1. A good roentgenogram must show the kidney outlines, psoas shadows and pelvis free from gas and fecal-filled shadows.

2. True immobilization of the patient, respiratory and otherwise, must be effected.

3. As low a kilovolt (peak) as consistent with the size of the patient is advocated by Pflaumer and Renander. The latter found that the density of a cystine stone decreased with an increase in kilovolts (peak). At 50 kv. (peak) the roentgenographic density was 3.8 while at 90 kv. (peak) it was 3.0. They advise a kilovoltage below 63 kv. (peak) for the best results.

4. Spot films of the suspected regions are of help.

5. The fundamental principles of roentgenography obtain: small focal spot, small object film distance, etc.

10. THE PROBLEM OF RADIOPACITY OR RADIOLUCENCE OF CYSTINE CALCULI

Textbooks and the medical literature contain much conflicting evidence on this subject. In an attempt to reach a reasonable solution to this problem substantiated by accurate statistics, the literature has been reviewed back to 1920. This period was chosen as including a sufficient number of cases to be conclusive and to be a period in which technique, apparatus and film quality gave some assurance that a negative report was of value rather than that some factor mentioned above was deficient.

In an earlier section, the theoretical and experimental proof that cystine calculi should be visible even when small has been demonstrated. From the literature during the last eighteen years, 69 undisputed cases of cystine stones having had roentgenological examinations were collected and to these I have added 6 cases, making a total of 75 cases. These represent the first examination only and no repeat examinations for recurring calculi have been included in this series. In other words, this group of cases represents new patients confronting the roentgenologist with the problem to rule urinary calculi either in or out. In 69 of the 75 cases the calculi were definitely visualized. Five of those not visualized were ureteral stones which are admittedly the most difficult to visualize. The other stone was reported by Kaemell and Graves as giving no shadow in the renal pelvis.

Criticism may be forthcoming that not in all instances are these pure cystine in composition. In the tabulation of these 75 cases (Table II), the original author's own estimate of the composition of his calculi has been recorded whenever this was given. On the basis of this compilation, it seems

TABLE II

TABULATION OF 69 CYSTINE URINARY STONE CASES TAKEN FROM THE LITERATURE WITH 6 CASES OF THE AUTHOR

Case	Date	Author	Male	Female	Radiopaque	Radiolucent	Constitution
1	1920	Jacoby	25 yr.	—	Yes	—	Pure cystine
2	1920	Beer	20 yr.	—	Yes	—	Pure cystine
3	1922	Macalpine	8 yr.	—	Yes	—	Cystine
4	1922	Graves	—	26 yr.	No	In kidney pelvis	Pure cystine
5	1923	Tennant	—	21 yr.	Yes	—	93% cystine
6	1924	White	—	32 yr.	Yes	—	Pure cystine
7	1924	Flood	3 yr.	—	Yes	—	Cystine
8	1924	Harris	—	16 yr.	Yes	—	Cystine with a trace of calcium phosphate
9	1924	Edwards	36 yr.	—	Yes	—	Pure cystine
10	1924	Crowell	—	27 yr.	Yes	—	Pure cystine
11	1925	Stallman	—	9 yr.	Yes	—	Cystine
12	1925	Stallman	2¾ yr.	—	Yes	—	Cystine
13	1925	Reaves	—	27 yr.	Yes	—	Cystine
14	1925	Kearns and Seeger	16 yr.	—	Yes	—	Cystine
15	1929	Assmann	Data incomplete		Yes	—	Cystine
16	1929	Sylla	—	38 yr.	Yes	—	Pure cystine
17	1929	Sum-Schick	32 yr.	—	Yes	—	Pure cystine
18	1929	Thevenot	—	14 yr.	Yes	—	Pure cystine
19	1930	Henline	29 yr.	—	Yes	—	Cystine
20	1930	Henline	—	30 yr.	Yes	—	Cystine
21	1930	Henline	16 yr.	—	Yes	Invisible until 0.5 cm.	Cystine
22	1931	Hicks	26 yr.	—	No	Small ureteral stone	Pure cystine
23	1931	Steinitz and Remen	36 yr.	—	Yes	—	Cystine
24	1931	Thomas and Rodda	4 yr.	—	Yes	—	Pure cystine
25	1931	Sacchi	24 yr.	—	Yes	—	Cystine
26	1932	Ewell	26 yr.	—	Yes	—	Pure cystine
27	1932	Ewell	4 yr.	—	Yes	—	Cystine
28	1932	Ewell	57 yr.	—	Yes	—	Cystine mixed stones
29	1932	Ewell	19 yr.	—	Yes	—	Pure cystine
30	1932	Walther and Pollak	31 yr.	—	Yes	—	Nearly pure cystine
31	1932	Walther and Pollak	Data incomplete		Visible	—	Cystine
32	1933	Kretschmer	9 yr.	—	Yes	—	Pure cystine
33	1933	Kretschmer	9 yr.	—	Yes	—	Pure cystine
34	1933	Kretschmer	12 yr.	—	Yes	—	Pure cystine
35	1933	Kretschmer	—	22 yr.	Yes	—	Cystine mixed stone
36	1933	Kretschmer	—	28 yr.	No	Small ureteral which passed	Cystine plus uric acid
37	1933	Walters and Castleton	14 yr.	—	Yes	—	Almost pure cystine
37	1933	Walters and Castleton	33 yr.	—	Yes	—	Almost pure cystine
39	1934	Pflaumer	Data incomplete		Yes	—	Cystine
40	1934	Pflaumer	Data incomplete		Yes	—	Cystine
41	1934	Pollak	—	44 yr.	Yes	—	Pure cystine
42	1934	Pollak	26 yr.	—	Yes	—	Cystine and calcium phosphate

TABLE II—*Continued*

Case	Date	Author	Male	Female	Radiopaque	Radiolucent	Constitution
43	1934	Patch	4 yr.	—	Yes	—	90% pure cystine
44	1934	Patch	17 yr.	—	Yes	—	90% pure cystine
45	1935	Curchod	—	25 yr.	Yes	—	Pure cystine
46	1935	Lee and Herman	31 yr.	—	Yes	—	Pure cystine
47	1935	Lee and Herman	13 yr.	—	Yes	—	Pure cystine
48	1935	Ashcraft	—	18 yr.	Yes	—	Cystine
49	1936	McKay	14 yr.	—	Yes	—	Cystine
50	1937	Paillard and Paillard	24 yr.	—	Yes	—	Pure cystine
51	1937	Paillard and Paillard	—	54 yr.	Yes	—	Pure cystine
52	1937	Paillard and Paillard	34 yr.	—	Yes	—	Cystine mixed stone
53	1938	Renander	15 yr.	—	Yes	—	3 stones—ash content 0.03%, 0.09% and 0.2% —pure cystine
54	1938	Renander	7 yr.	—	Yes	—	Ash content 1.22%—trace of Ca triple phosphate
55	1938	Renander	—	40 yr.	Yes	—	Ash content 0.1% pure cystine
56	1938	Renander	19 yr.	—	Yes	—	Ash content 0.02%—pure cystine
57	1938	Renander	20 yr.	—	Yes	—	Ash content 2.7%—pure cystine
58	1938	Renander	13 yr.	—	Yes	—	4 stones—ash content 0.5% to 5%, average 2.4%, majority pure cystine
59	1938	Renander	18 yr.	—	Yes	—	Almost pure cystine
60	1938	Renander	—	34 yr.	Yes	—	Pure cystine
61	1938	Renander	50 yr.	—	Yes	—	82.1% cystine and 85.8% cystine Ca. Tr. phos. and and Mg am. phos. traces
62	1938	Renander	69 yr.	—	Yes	—	Laminated 77.01%, 83.1%, 97.91% cystine. Ca triple phosphate was the principal impurity
63	1938	Renander	33 yr.	—	Yes	—	Bladder 7.62% ash content. Kidney 2.46% ash content. Ca triple phosphate was principal impurity
64	1938	Renander	24 yr.	—	Yes	—	Ash content 0.61% to 0.23%. Pure cystine
65	1938	Renander	22 yr.	—	Yes	—	Ash content 0.30% Ca triple phosphate pure cystine
66	1938	Renander	—	23 yr.	Yes	—	Pure cystine
67	1938	Renander	52 yr.	—	No	Ureteral	Pure cystine
68	1938	Renander	—	42 yr.	No	Ureteral	Ash content 0.02%, pure cystine
69	1938	Renander	39 yr.	—	No	Ureteral	Cystine
70	1938	Morrison	—	48 yr.	Yes	—	0.65% ash content of which 18.2% was calcium and 17.4% phosphorus
71	1938	Morrison	35 yr.	—	Yes	—	Negligible ash. No quantitative studies done

Table II—*Continued*

Case	Date	Author	Male	Female	Radiopaque	Radiolucent	Constitution
72	1938	Morrison	—	39 yr.	Yes	—	0.12% ash of which 27.7% was calcium and 16.2% phosphorus
73	1938	Morrison	22 yr.	—	Yes	—	Three specimen of large and small stones had no ash. Pure cystine
74	1938	Morrison	—	17 yr.	Yes	—	Three specimen of small and large stones had no ash. Pure cystine
75	1938	Morrison	7 yr.	—	Yes	—	Negligible ash. No quantitative studies

A statistical study of 75 collected cases of cystine urinary calculi. Sixty-nine, or 92 per cent, were radiopaque and 6, or 8 per cent, were radiolucent. Of the 6 radiolucent stones, 3 being in males and 3 in females, 5 were small ureteral calculi and 1 was in the kidney pelvis.

48 Males (68%) 23 Females (32%) 4 cases, data not complete

Oldest case—69 years, male *Youngest case*—2¾ years, male

Average age: male—23 years; female—27 years; combined 25 years.

proved that practically all cystine calculi, and by this is meant even those of pure cystine constitution, should be visible above a size which usually gives symptoms.

Reviewing these cases made another fact quite obvious. The problem resolves itself into not so much the question whether pure cystine stones are or are not visible but whether the stones which cystinurics form, regardless of the traces of other elements present in them, are visualized or not. To this question the answer is most emphatically to the affirmative.

To summarize the evidence presented by other investigators: Kaemell and Graves contend that pure cystine stones are not visible on the roentgenogram. They report a 1.7×1.7×1.0 cm. pure cystine stone which was seen only as a negative shadow by retrograde pyelography. The patient was an obese female. They passed a capsule of cystine crystals through a patient and were unable to visualize it on a film, while a capsule of bismuth was readily seen. The validity of this experiment may be questioned in view of Arcelin's work pointing out the importance of molecular concentration in determining the radiodensity of a substance.

Since the substance responsible for the radiopacity of cystine is sulphur, Henline prepared stones of different sulphur contents of which he made roentgenograms. From this he concluded that any stone containing 25 per cent sulphur will be visualized.

Schinz (1932) states that the density of cystine as compared to water is 3.7 and Telemann, using a smaller factor of multiplication, computed it theoretically as 1.18.

Renander (1938) seems to have made a most thorough investigation of this subject using a photometric method. This ingenious method was to compare photometrically the density of the cystine stones of his collected cases with a stepladder of aluminum and then by the same procedure compare the latter to water. From his study of 15 cases he estimated that the radiopacity of these stones as compared to water was 3.5 when the ash content was less than 2 per cent and ran as high as 4.4 with an ash content above 10 per cent. This higher figure is due to the presence of inorganic substances which the increased ash content would indicate. His average figure was 3.8. He went further to show that a cystine stone with a diameter of 0.1 cm. produced a shadow 22 per cent more dense than the soft tissues of the neighborhood and a 3.0 cm. stone would produce a shadow 300 per cent more dense. By synthesizing concretions out of cystine and gum arabic, he arrived at the density as compared to water to be 2.9. He then reported 17 cases which he had collected and

Fig. 1. Case 1. Cystinuric. Staghorn calculus in left renal pelvis. Chemical analysis proved it to be practically pure cystine with 0.65 per cent ash content. Analysis of the ash showed 18.2 per cent calcium and 17.4 per cent phosphorus.

of these 14 were visualized; the 3 not visualized were in the ureters.

Nakano analyzed 7 cystine stones with the following results: cystine 89.1 per cent, P_2O_2 1.3 per cent, Na 2.8 per cent, K 0.1 per cent, Ca 1.02 per cent, H_2O 2.26 per cent, total nitrogen 10.73 per cent.

11. Roentgenographic Diagnosis

The differentiation of cystine calculi from other urinary calculi is not always possible by roentgenographic examination alone. The review of these 75 cases, however, pointed out certain constant diagnostic criteria:

1. Homogeneity in density and constitution of all the more chemically pure calculi.
2. Their waxy appearance even on the roentgenogram.
3. The round, smooth contour of the individual stones.
4. The radiodensity slightly less than that of equal-sized calculi with calcium and phosphorus content.
5. The tendency toward staghorn formation.
6. Confluences of smaller stones in dilated calyces.
7. Bilateral tendencies.
8. Radial crystalline structure peripherally in the larger stones.

Two of our cases and scattered cases in the literature have definite diagnostic features (Ewell, Kearns and Seeger, Thomas and Rodda, Steinitz and Remen, Walters and Castleton). In the cases mentioned, bilateral involvement was the rule and a small staghorn calculus was usually visualized in at least one renal pelvis. The calyces for the most part were hydronephrotic and filled with confluent collections of rounded, oval, or rounded polyhedral, smooth stones with a very slight tendency toward facetting, varying in size from grains of sand to 1 cm. in diameter. They all had a waxy, homogeneous appearance even in the roentgenogram (see Figs. 4*A* and 5*A*).

Unfortunately, this picture represents a rather advanced stage of renal damage with low factor of safety or even borderline uremia. However, the solitary or bilateral staghorn calculi of homogeneous, waxy appearance with density less than that of similar sized stones with calcium or phosphorus content should be considered for the diagnosis of cystine calculi. The solitary ureteral or renal calculus can only be suspected for their waxy, homogeneous, rounded appearance.

12. Case Reports

Case 1 (Hosp. U-26004). Mrs. R. F., aged forty-eight, housewife, entered the hopsital on September 10, 1928, complaining of symptoms of right ureteral colic of two days' duration. An abdominal roentgenogram taken at the time was reported as unsatisfactory due to motion and bowel contents. This examination was not repeated since a retrograde catheter met the obstructing calculus which was removed by right ureterotomy. She returned nine years later to the Out-Patient Department complaining of right upper quadrant pain which had been intermittent for several years and quite severe for the preceding three months. She was treated without success by the orthopedic service since the staghorn calculus visualized by roentgen ray in her left kidney would not ex-

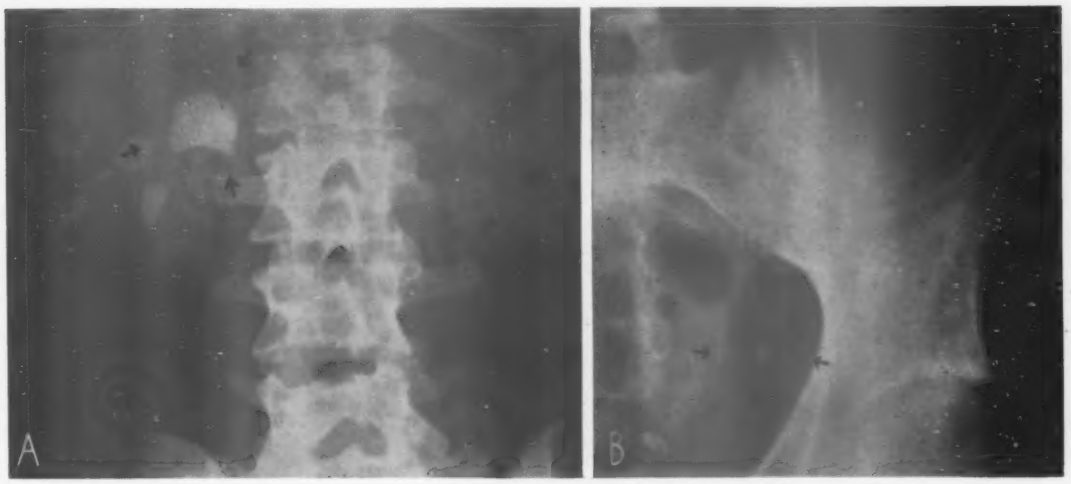


Fig. 2. Case II. Cystinuric. *A*, large renal calculus on the right. This has not been removed. No analysis. *B*, impacted left ureteral calculus which chemically was cystine. No quantitative analysis made.

plain her right-sided symptoms. For a month before her final entry, December 14, 1937, she had passed gravel and stones with alternating right- and left-sided pain. The staghorn calculus was removed from her left kidney pelvis by pyelolithotomy (Fig. 1). Urinary examinations revealed cystinuria.

Analysis of this calculus proved it to be practically pure cystine with an ash content of 0.65 per cent. Analysis of the ash showed 18.2 per cent calcium and 17.4 per cent phosphorus.

Follow-up roentgenograms demonstrated several small calculi in the lower pole of her left kidney. Attempts at alkalinization were made but the plan of treatment was not followed.

Case II (Hosp. U-96438). T. D., male, arthritic, aged thirty-five, had his first attack of renal colic with hematuria in March, 1936. A large calculus was demonstrated by roentgen examination in the right renal pelvis (Fig. 2*A*) and an impacted left ureteral stone resulting in a non-functioning kidney on that side was also visualized (Fig. 2*B*). The latter was surgically removed. He still retains the renal calculus without symptoms. The cystinuria has been under treatment with sodium citrate. No new stones have been found subsequently.

Qualitative analysis of the calculus proved it to be cystine. No quantitative analysis was done.

Case III (Hosp. U-35280). Mrs. M. W., aged thirty-nine, housewife, entered the hospital on April 14, 1936, with the history of having stones at the rate of approximately one a year for the preceding twenty-two years, her symptoms being equally divided between the right and left sides. Roentgenograms of her abdomen revealed bilateral staghorn calculi (Fig. 3). The left renal calculus was removed. The patient refused further surgery and has been lost track of.

Analysis of the stone proved it to be practically pure cystine with an ash content of 0.12 per cent. The ash content consisted of 27.7 per cent calcium and 16.2 per cent phosphorus.

Fig. 3. Case III. Bilateral staghorn calculi visible. The left one only was removed. Chemically it was practically pure cystine with an ash content of 0.12 per cent of which 27.7 per cent was calcium and 16.2 per cent phosphorus.

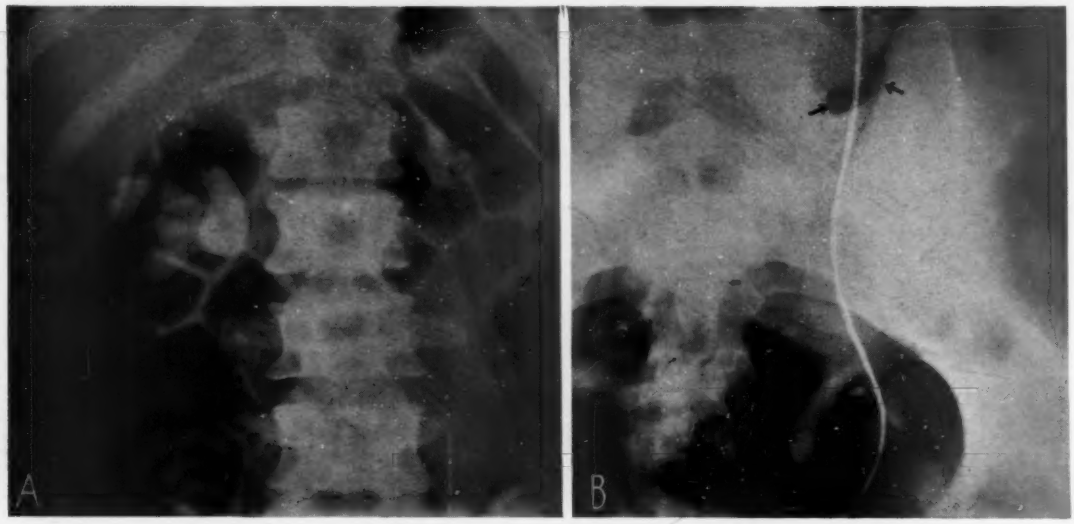
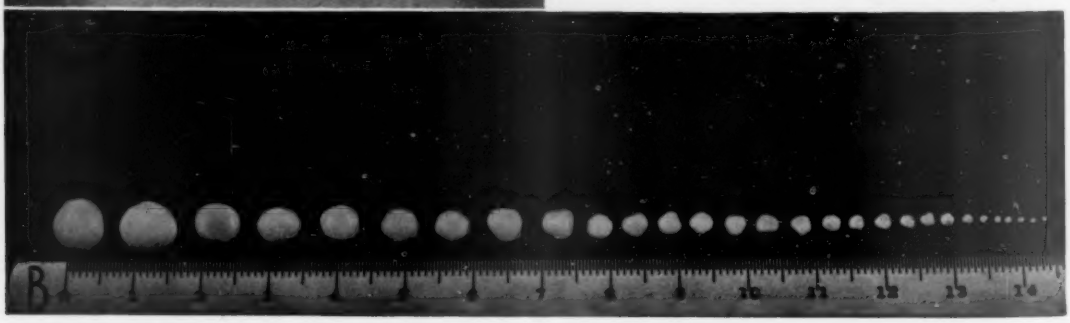


Fig. 4. Case IV. Cystinuric. *A*, right kidney contains a staghorn calculus and groups of small stones in dilated calyces. This nephrotic kidney was removed. Chemical analysis of the staghorn calculus proved it to be pure cystine with no ash. Several small stones showed 0.06 per cent ash content of which 19.3 per cent was calcium. Several small stones are seen in the left kidney. This roentgenogram seems to be significant in diagnosing cystine calculi. See also Figure 5. *B*, film of the impacting multiple left ureteral stones causing the admission symptoms. These were cystine but not quantitatively analyzed.

Fig. 5. Case V. Cystinuric. *A*, bilateral multiple renal calculi. Each pelvis has a large stone. The right kidney has several groups of small stones and sand in dilated calyces. The dilated pelvis and calyx system of the left kidney is crowded full of tuft-like conglomerations of stones principally below 5 mm. in size with a suggestion of facetting. These have a density less than calcium and phosphorus stones of the same size. This finding is very suggestive of cystine lithiasis and should be borne in mind when making a differential diagnosis of urinary calculi. It is a late manifestation. Samples of both large calculi and of the smaller stones in both kidneys were chemically pure cystine with no ash content (compare with Fig. 4*A*). *B*, size and shape of stones removed from the dilated calyces of the left kidney which were visible in the roentgenogram and found to be pure cystine chemically without ash content.



Case iv (Hosp. U-104358). R. G., male, aged twenty-two, laborer, in 1926 had been in an automobile accident, immediately followed by left flank pain and hematuria. This subsided but three months later he had another attack of left flank pain lasting several days. These attacks recurred fourteen and six months before admission and were accompanied by nausea, vomiting, and the passage of a stone in the last instance. He entered the hospital January 17, 1938, having had constant left flank pain for five days. Roentgenograms revealed bilateral renal stones and multiple ureteral stones on the left (Fig. 4*A* and *B*). A left ureterolithotomy was performed January 28, 1938, and on February 21, 1938, an almost completely destroyed hydronephrotic kidney full of stones was removed on the right. Since the patient had cystinuria, he was alkalinized and has been well except for a urinary infection for over a year.

Analysis of the staghorn calculus showed pure cystine with no ash. Several small stones analyzed (5 mm. or less in size) showed 0.06 per cent ash, 19.3 per cent of which was calcium. The left ureteral stones were cystine, not quantitatively analyzed.

Case v (Hosp. U-108077). R. E. C., female, aged eighteen, schoolgirl, for five years had suffered from intermittent left flank pain with nausea and vomiting lasting about two weeks at a time which had been treated as pyelitis. These attacks became more frequent in 1937, practically incapacitating her. Roentgenograms, February 1, 1938, showed bilateral staghorn calculi with numerous small stones in clumps and some sand in hydronephrotic kidneys (Fig. 5*A*). On March 1, 1938, her right kidney was removed and was found to be a hydronephrotic sac containing a large stone and collections of small stones in dilated calyces. She had cystinuria and was alkalinized. On March 19, 1938, the stones from the left kidney were removed as completely as possible. Her convalescence was stormy and since recovery she has passed numerous stones with a coincident reduction in the number of stones overlying her kidney shadow as seen roentgenographically.

Stones from her right kidney were found to be pure cystine with no ash content. The large stone in her left kidney and samples of stones 0.2 and 0.4 cm. in diameter on analysis were also pure cystine with no ash content. (See Fig. 5*B* for examples of stones analyzed.)

Fig. 6. Case vi. Cystinuric. Staghorn calculus in the right pelvis with several small stones seen to lie within the right kidney. There is a large oval calculus in the pelvic ureter and a smaller round one over the sacrum. These stones were chemically cystine. No quantitative examination was done. Several calcified glands are also present and show the greater density of their calcium content.

Case vi. (Private case of Dr. Fuller Albright of this hospital and Dr. Edward Pearson of Salem.) H. M., aged seven, schoolboy, passed his first stone at the age of nine months and passed numerous stones up to the time of observation. Roentgenograms taken in June, 1934, demonstrated several stones, including a staghorn calculus, in the right kidney. A large oval and a small round calculus were also visualized in the right ureter (Fig. 6). Several calcified glands were also present and showed the greater density of their calcium content. The patient, his father and mother were cystinurics. The latter had never formed stones. A right nephrectomy removed a destroyed hydronephrotic kidney. The contained stones were cystine. No quantitative determinations were done. He was alkalinized and remained symptom free when last seen four and a half years later.

13. Summary and Conclusions

The one hundred twenty-eight year progress in the knowledge of cystinuria and

cystine lithiasis has been reviewed. The physical, chemical and metabolic characteristics of the essential amino acid, cystine, and its rôle in the production of calculi have been discussed.

The incidence of cystinuria in the population at large is not more than 1 in 1,000 Only 2.5 per cent of cystinurics at most develop calculi. The relative frequency of cystine calculi to other urinary stones is estimated at 1 per cent. The majority of those affected are males, only 25 per cent being in females. One-quarter of the cases are discovered in the first two decades. Cystine lithiasis is usually a bilateral affliction and persistent through life in otherwise healthy individuals. The hereditary aspects of this disease are demonstrated. Alkalinization and other suggested therapeutic aids are mentioned.

The radiopacity of pure cystine stones is established both experimentally and clinically and the factors contributing to their visualization or non-visualization are discussed. Sixty-nine well proved cases have been collected from the literature over the last eighteen year period and the author adds 6 cases, making a series of 75.

In 69 of these the calculi were definitely visualized. Of the 6 not visualized, 5 were ureteral and only 1 was in the kidney pelvis. This 8 per cent failure in visualization compares not too unfavorably with the estimates in the literature ranging from 2 per cent to 16 per cent non-visualization for ureteral stones in general.

The care in technique to demonstrate cystine as well as other urinary calculi is emphasized. A plea for the tracing of every urinary calculus from the roentgenographic shadow to its chemical constitution is made in order to clarify the statistics concerning the prevalence of cystine stones. If the rather difficult quantitative determination of calculi is not possible, the simple process of determining the percentage of ash gives a good index of the amount of inorganic substance present.

The roentgenographic diagnosis of cystine calculi in the urinary tract was highly suggestive in advanced cases. The diagnostic criteria are stressed which should aid in the differential diagnosis of not only multiple calculi but of staghorn stones and even raise the suspicion that some small, solitary urinary calculi are of cystine constitution.

Grateful acknowledgment is made to Dr. George W. Holmes, Dr. Richard Schatzki, and Dr. Fuller Albright for help and advice; to Dr. George G. Smith for the use of clinical material; to Dr. Fuller Albright and Dr. Edward Pearson for the inclusion of one of their cases; and to Dr. Hirsh Sulkowitch and Mrs. Esther Gordon for chemical analysis of the calculi.

REFERENCES

1. Arcelin. Encyclopédie francaise d'urologie. A. Pousson and E. Desnos, Paris, 1914–1921, Vol. 2, p. 156.
2. Ashcraft, L. T. Large cystine calculus impacted in pelvic ureter. *Urol. & Cutan. Rev.*, 1935, *39*, 774–776.
3. Assmann, H. Die klinische Röntgendiagnostik der inneren Erkrankungen. F. C. W. Vogel, Berlin, 1929.
4. Beer, E. Cystine nephrolithiasis. *Internat. J. Surg.*, 1920, *33*, 219.
5. Beumer, H., and Wepler, W. Über die Cystinkrankheit der ersten Lebenszeit. *Klin. Wchnschr.*, 1937, *16*, 8–10.
6. Braasch, W. F., and Foulds, G. S. Postoperative results of nephrolithiasis. *J. Urol.*, 1924, *11*, 525–537.
7. Crowell, A. J. Cystin nephrolithiasis. *Surg., Gynec. & Obst.*, 1924, *38*, 87–91; also, *J. Urol.*, 1924, *11*, 545–557.
8. Curchod, H. Cystine renal calculi. *Rev. méd. de la Suisse Rom.*, 1935, *55*, 29–36.
9. Edwards, H. C. Cystinuria with calculus formation. *Brit. J. Surg.*, 1924, *12*, 345–350.
10. Ewell, G. H. Cystine nephrolithiasis. *J. Am. M. Ass.*, 1932, *99*, 2160–2166.
11. Flood, H. C. Cystinuria and cystin calculi. *Atlantic M. J.*, 1923–1924, *27*, 141–143.
12. Garrod, A. E. Cystinuria and Cystine Lithiasis. Oxford Med., Clarenden Press, 1931.
13. Gortner, R. A., and Hoffman, W. F. Chemical study of cystine from kidney stones. *Proc. Soc. Exper. Biol. & Med.*, 1926, *23*, 691–693.
14. Graves, R. C. Diagnosis of shadowless renal calculi. *Ann. Surg.*, 1922, *75*, 487–491.
15. Harris, A. Cystinuria. *Surg., Gynec. & Obst.*, 1924, *38*, 640–645.
16. Henline, R. B. Cystine calculi. *Am. J. Surg.*, 1930, *8*, 581–592.
17. Herman, L., and Lee, W. E. Cystine nephrolithiasis. *Ann. Surg.*, 1935, *101*, 746–753.

18. Hicks, J. B. Cystinuria complicated by cystine calculi. *New England Med. J.*, 1931, *205*, 1001–1004.
19. Jacoby, M. Zur Nephrolithiasis bei Zystinurie. *Berl. klin. Wchnschr.*, 1920, *57*, 446–448.
20. Kamil, F. Einige interessante Fälle aus dem Gebiete der Urologie. *Ztschr. f. Urol.*, 1935, *29*, 554–561.
21. Kearns, W. M., and Seeger, S. J. Cystinuric lithiasis. *J. Am. M. Ass.*, 1925, *85*, 4–7.
22. Kretschmer H. L. Cystinuria and cystin stones with report of a new family of cystinurics. *Urol. & Cutan. Rev.*, 1916, *20*, 1–10.
23. Kretschmer, H. L. Cystinuria and cystin stones. *J. Urol.*, 1933, *30*, 403–420.
24. Kretschmer, H. L. *Tr. Am. Ass. Genito-Urin. Surgeons*, 1933, *26*, 241.
25. Lewis, H.B. Occurrence of cystinuria in healthy young men and women. *Ann. Int. Med.*, 1932. *6*, 183–192.
26. Lignac, G. O. E. Cystin metabolism in children. *Arch. f. klin. Med.*, 1924, *145*, 139–150.
27. Looney, J. M., Berglund, H., and Graves, R. C. Study of several cases of cystinuria. *J. Biol. Chem.*, 1923, *57*, 515–531.
28. Macalpine, J. B. Specimen of cystin calculi from kidney of a child. *Proc. Roy. Soc. Med.*, 1921–1922, *15* (Sect. Urol.), 36.
29. McKay, R. W. Cystin stones. *South. Med. & Surg.*, 1936, *98*, 367–370.
30. Mörner, C. T. Cystin calculi. Abs. in *J. Am. M. Ass.*, 1921, *76*, 560.
31. Nakano, H. Atlas der Harnsteines. F. Deutcke, Leipzig, 1925.
32. Paillard, H., and Paillard, M. H. Quatre cas de calculs de cystine des voies urinaires. *J. méd. franç.*, 1937, *26*, 135–139.
33. Patch, F. S. Cystinuria and cystine lithiasis. *Canad. M. Ass. J.*, 1934, *31*, 250–255.
34. Peterson, H. O., and Holmes, G. W. Roentgen analysis of 100 cases of ureteral stone. Am. J. Roentgenol. & Rad. Therapy, 1937, *37*, 479–483.
35. Pflaumer, E. Nichtschattengebende Harnsteine. *München. med. Wchnschr.*, 1934, *91*, 483–491.
36. Pollak, W. Case of bilateral coral stones composed of cystin. *Urol. & Cutan. Rev.*, 1932, *36*, 793–798.
37. Pollak, W. Ueber Cystinsteine. *Ztschr. f. Urol.*, 1934, *28*, 480–483.
38. Reaves, J. U. Treatment of cystin stone. *South. M. J.*, 1925, *18*, 599–603.
39. Renander, A. In Schweden röntgenuntersuchte Fälle von Zystinurie mit Konkrementbildung. Eine Untersuchung über die Röntgendichtigkeit der Zystinsteine. *Acta radiol.*, 1937, *18*, 807–841.
40. Sacchi, M. La cistinolitiasi. *Minerva med.*, 1931, *1*, 948–952.
41. Schinz, H. R., Baensch, W., and Friedl, E. Lehrbuch der Röntgendiagnostik. Georg Thieme, Leipzig, 1932.
42. Stallman, J. F. H. Cystinuria in children, with renal and vesical cystin calculi respectively. *Lancet*, 1925, *2*, 375–378.
43. Steinitz, H., and Remen, L. Zystinurie mit doppelseitigen Nierensteinen. *Med. Klin.*, 1931, *27*, 1791–1792.
44. Sullivan, M. X. Studies on biochemistry of sulphur; further studies on distinctive reaction for cysteine and cystine. *Pub. Health Rep.*, 1929, *44*, 1421–1428.
45. Sullivan, M. X., and Hess, W. C. Studies on biochemistry of sulphur; chemical groups involved in naphthoquinone reaction for cysteine and cystine. *Pub. Health Rep.*, 1929, *44*, 1599–1608.
46. Sum-Schick, E. Zur Cystinuriefrage. *Ztschr. f. Urol.*, 1929, *23*, 985–988.
47. Sylla, A. Ein Fall von vorübergehender Cystinurie mit Ausscheidung von Cystein, Leucin und Thyrosin. *Med. Klin.*, 1929, *25*, 469–471.
48. Telemann, W. Untersuchungen über die röntgenologische Darstellbarkeit von Steinin des harnleitenden Apparates. *Deutsche med. Wchnschr.*, 1911, *37*, 977–980.
49. Tennant, C. E. Cystin calculi. *J. Am. M. Ass.*, 1923, *80*, 305–307.
50. Thevenot. Calcul renal bilatéral de cystine pure chez une fillette. *J. d'urol.*, 1929, *27*, 231–234; also, *Bull. Soc. franç. d'urol.*, 1929, *8*, 64–66.
51. Thomas, G. J., and Rodda, F. C. Multiple cystin calculi in left kidney with obstruction at ureteropelvic juncture and multiple cystin calculi in bladder in boy of four years. *Tr. Am. Ass. Genito-Urin. Surgeons*, 1930, *23*, 451–458; also, *Journal-Lancet*, 1931, *51*, 538–541.
52. Walters, W., and Castleton, K. B. Cystine renal calculus. *West. J. Surg.*, 1933, *41*, 622–627.
53. White, H. P. W. Radiographic features of urinary calculi in relation to their chemical composition and structure, with special reference to renal calculi. *Brit. J. Surg.*, 1924, *12*, 5–27.

THE VERTEBRAL COLUMN IN ACROMEGALY*

By WILLIAM CHESTER, M.D.
MAMARONECK, NEW YORK
and
EDWARD M. CHESTER, M.D.
Resident in Medicine, Montefiore Hospital
NEW YORK CITY

ALTERATIONS in the vertebral column in acromegaly were described by Pierre Marie[10] and his coworkers.[11,12] These changes frequently give to the acromegalic the pronounced lower dorsal kyphosis. Atkinson,[2] in an analysis of the literature, found kyphosis present in 351 of 584 patients with acromegaly. An additional number of 82 patients had a kyphoscoliosis. The detailed anatomical studies of Virchow,[15] von Recklinghausen,[13] Arnold,[1] and others[5,6,14] interested in this subject, mention the enlargement of the vertebrae and an associated spondylitis. Erdheim,[7] in 1931, showed that this alteration in the configuration of the vertebral column in acromegaly is referable to characteristic changes in the bodies of the vertebrae and in the adjacent intervertebral discs, and that there is often an associated specific spondylitis. One year later de Langen and Zainal[9] were able to demonstrate these findings by roentgen studies. Our purpose is to present the roentgen findings in the vertebral columns of 8 patients with acromegaly.

Many of the following criteria for the diagnosis of acromegaly were present in each of our patients: overgrowth of the hands, feet, face and skull; exaggeration of numerous superficial bony ridges and excrescences; enlargement of the nose, ears, tongue and lips; prognathism; enlargement of the sella turcica, at times associated

TABLE I

PATIENTS WITH ACROMEGALY

Roentgen Changes in the Vertebral Column

Case	Age	Kyphosis	Large Vertebrae	Increase in Anteroposterior Diameter of Dorsal Vertebrae	Symmetrical Spondylitis
I. J. R.	59	Marked lower dorsal	Present	Present	Present
II. I. S.	25	Absent	Present	Absent	Absent
III. P. M.	51	Slight lower dorsal	Present	Present	Present
IV. E. P.	43	Marked lower dorsal	Present	Present	Present
V. J. H.	59	Slight lower dorsal	Present	Present	Present
VI. A. G.	48	Slight lower dorsal	Present	Present	Absent
VII. D. M.	51	Absent	Absent	Absent	Slight
VIII. L. S.	47	Absent	Present	Absent	Present

* From the Medical Service of Dr. L. Lichtwitz and the Roentgen Department of Dr. A. J. Bendick, Montefiore Hospital, New York City.

with erosion of the posterior clinoid processes; enlargement of the nasal accessory sinuses; tufting of the terminal phalanges; large bones; prominence of the costochondral junctions; and changes in the joints. In addition, many of the patients showed an abnormal sugar metabolism and an increased rate of energy exchange.

CASE REPORT

The changes in the vertebrae in our group of patients are presented in Table 1. Case IV is given in detail because of some unusual findings.

Case IV. E. P., aged forty-three, was admitted to the Montefiore Hospital in November, 1933. Because of changes in his features at the age of thirty-three, he was told he had acromegaly. Five years later enlargement of the hands and feet, polydipsia, and polyuria appeared. One year before admission his vision began to fail. In September, 1933, at another institution, a roentgen diagnosis of osteitis fibrosa cystica of the left humerus was made.

Fig. 1. Case IV. Increased anteroposterior diameter of the bodies of the lower dorsal vertebrae.

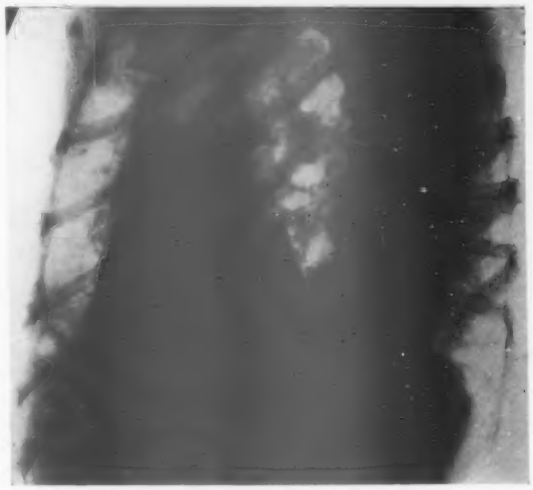


Fig. 2. Case IV. Symmetrical spondylitis of the lower dorsal vertebrae.

On examination the patient was found to be a typical acromegalic. The head, nose, ears, and lips were large. The tongue and tonsillar pillars were massive. The lower jaw was prognathic and the malar bones were prominent. The eyebrows were shaggy. The pupils reacted to light and accommodation. Bilateral exophthalmos, bitemporal hemianopsia, and bilateral optic atrophy, more marked on the left than on the right, were present. The thorax was large, particularly in the anteroposterior diameter. A marked dorsal kyphosis and a moderate degree of lumbar lordosis were present. There was thickening of the costochondral junctions. Irregularities in the bony contour could be felt on the lateral aspect of the proximal portion of the humeri. Axillary hair was absent.

Cardiac enlargement could not be demonstrated. The heart sounds were normal. The blood pressure was 130 systolic and 70 diastolic. The lungs and abdomen were negative. The pubic hair was of female distribution. The genitalia were small. The hands and feet were large, the former spade-like. Marked genu valgum was present. The skin of the hands and feet was thickened. Manipulation of the knee joints produced a crackling sensation resembling rice bodies.

Laboratory Data. The Wassermann test was negative. Gastric analysis showed free hydrochloric acid after histamine. The glucose tolerance test after 30 gm. of sugar revealed the following values: fasting, 82 mg.; one-half hour, 133 mg.; one hour, 104 mg.; two hours, 87 mg.;

Fig. 3. Case IV. Cystic areas in the greater trochanter, pubic bones, and about the sacroiliac synchondrosis.

three hours, 74 mg. per 100 cc. The serum proteins were 4.12 gm. per 100 cc., of which albumin was 3.9 and globulin 0.22. Blood calcium was 10.2 mg.; phosphorus 4.8 mg. The other blood chemical analyses and blood count were not remarkable. The basal metabolic rate was −1 per cent, −3 per cent. The urine showed no abnormalities.

Roentgen Findings. The sella turcica was markedly enlarged and the posterior clinoid process was thinned out and displaced posteriorly. The floor of the sella turcica could not be distinctly visualized.

The thorax was broad, particularly in its anteroposterior diameter. A kyphosis of the lower dorsal region and a lumbar lordosis were present. The anteroposterior diameter of the bodies of the lower dorsal vertebrae was considerably increased (Fig. 1). Symmetrical "parrot-beak-like" spondylitis was especially marked in the lower dorsal region (Fig. 2). The ribs were very broad. The humeral heads were somewhat flattened and numerous cystic areas were present in the necks. The acromial end of the clavicle and the acromial process were abnormally developed bilaterally. Cystic areas were also present in the bones about the knee joints and in the femora, and were especially marked in the greater trochanters, in the pubic bones, and about the sacroiliac synchondrosis (Figs. 3 and 4). In the feet and hands, the ends of the shafts of the metatarsal and metacarpal bones were thinner than normal. The carpal and tarsal bones showed marked atrophic changes with irregular areas of calcification. There was tufting of the terminal phalanges.

The patient's course in the hospital was uneventful. He was discharged after several months' observation.

DISCUSSION

Examination of Table 1 shows that a lower dorsal kyphosis was present in 5 of our 8 patients. Roentgenograms of the spine in these 5 instances showed an in-

Fig. 4. Case IV. Cystic areas in the bones forming the knee joint.

crease in the anteroposterior diameter of the bodies of the lower dorsal vertebrae. In all of these cases the anteroposterior diameter of the bodies of the lower dorsal vertebrae exceeded that of the lumbar vertebrae. In addition, 4 of these 5 patients showed a symmetrical spondylitis. Two of the patients without kyphosis showed a moderate degree of symmetrical spondylitis. Seven cases showed large vertebrae.

Normally, a lateral roentgenogram of the vertebral column will show the anteroposterior diameter of the bodies of the lumbar vertebrae to equal or exceed that of the lower dorsal vertebrae. This normal relationship was observed in a control group of 100 cases.

In acromegaly there is often an increase in the anteroposterior diameter of the vertebral bodies beginning in the lower cervical and extending to the lumbar region. The most marked increase occurs in the lower dorsal region, so that the anteroposterior diameter of the bodies of the lower dorsal vertebrae exceeds that of the lumbar. What appears to be a decrease in the superior inferior diameter of the bodies of the lower (8th to 12th) dorsal vertebrae is a false impression gained through the increase in the anteroposterior diameter, the superior inferior diameter remaining unaffected (Fig. 5).

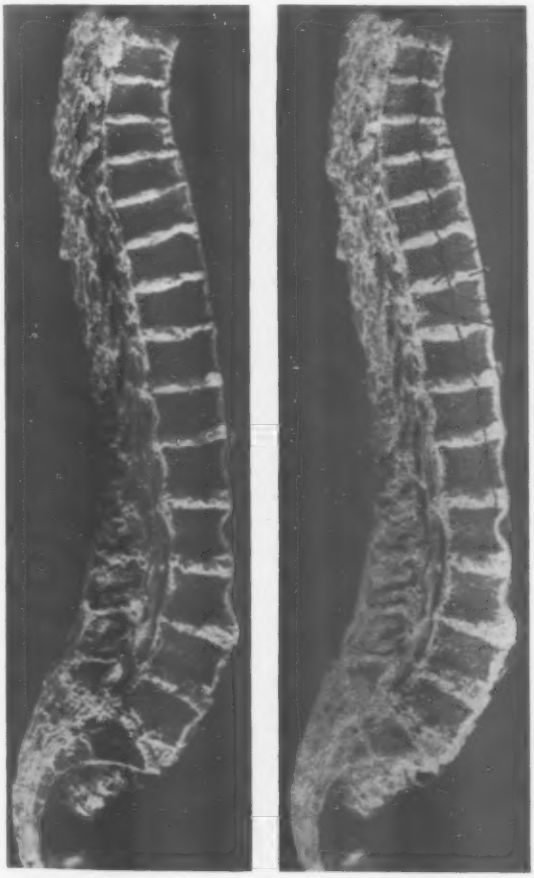


Fig. 5. Sagittal section of vertebral column indicating the additional growth of bone and intervertebral disc. (From Erdheim, p. 204.)

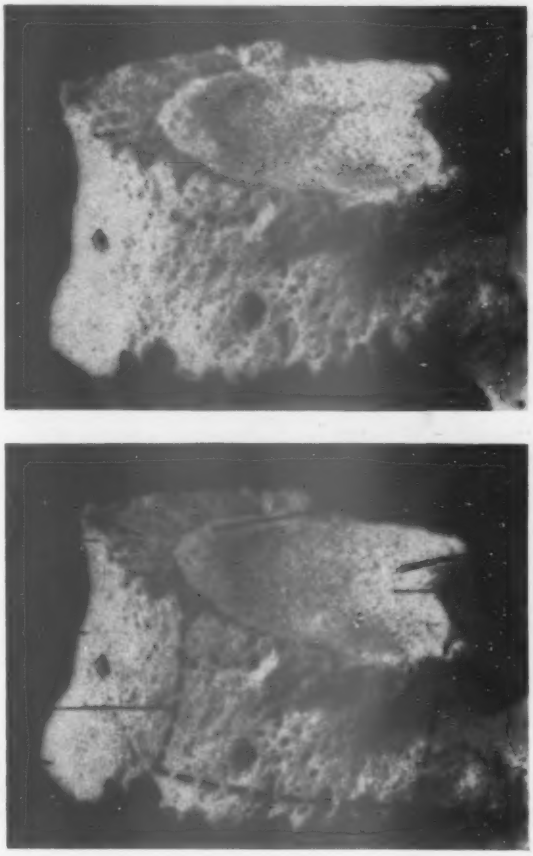


Fig. 6. Twelfth dorsal vertebra showing additional growth of bone: the old bone is demarcated by the broken line. (From Erdheim, p. 290.)

Erdheim's meticulous anatomic and correlated roentgenologic studies revealed that these charges are due to growth of new bone on the lateral and anterior aspects of the vertebral bodies (Fig. 6). In this fashion, the bodies of the vertebrae are

ensheathed on three sides by the deposition of new periosteal bone upon the diaphysis. The margins of this partial bony sheath are fissured so that a row of tooth-like processes appears above and below a vertebral disc. At times the growth of bone at the diaphysis is more marked peripherally than centrally. This gives rise to a spondylitis characterized by the symmetry of the spondylitic processes and is believed to be specific for acromegaly. This spondylitis is more pronounced laterally than anteriorly. Thus, the spondylitis of acromegaly is distinguishable from the usual spondylitis osteo-arthritica in that the former is of pituitary origin, while the latter is due to local degenerative changes in the discs and subsequent overgrowth of cartilage and bone. In the roentgenogram, the spondylitis of acromegaly can readily be detected by the symmetry of the spondylitic processes. In spondylitis osteo-arthritica, asymmetry of the spondylitic processes is the rule. The exostoses have a varied and often bizarre configuration, and bridging of vertebrae is not unusual. In some instances of acromegaly, a nonspecific spondylitis deformans is present on the posterior aspect of the vertebral body.

The growth of the intervertebral disc parallels that of the body of the vertebra, the new disc being laid down from the perichondrium. The new intervertebral disc is thinner than the old biconvex disc. Its margins are irregular and new bone may even protrude into the intervertebral disc.

Osteoporosis of the spine in elderly patients with acromegaly is described by Brigidi and Broco.[3] When present this condition may modify the picture somewhat.

The cystic areas in Case IV may represent increased parathyroid activity in the course of acromegaly. Curschmann[4] was one of the first to mention similar roentgen findings.

As a matter of interest, roentgenograms of the vertebral columns in 10 patients with hypertrophic pulmonary osteo-arthropathy were similarly examined. In one instance findings were present in the vertebrae suggestive of those described in acromegaly. The patient was a male, aged fifty, with bronchiectasis of the right middle and lower lobes, a bronchopleural-cutaneous fistula subsequent to thoracotomy for a lung abscess, amyloidosis, and a mild degree of right heart failure.

Clinically, the only finding to suggest acromegaly was the macroglossia. Roentgenograms of the osseous system showed the sella turcica and the accessory nasal sinuses to be normal. The ungual processes of the terminal phalanges were exaggerated and there was marked clubbing of the soft parts. The dorsal and lumbar vertebrae showed a moderate nonspecific hypertrophic spondylitis. There was, in addition, a very slight increase in the anteroposterior diameter of the lower dorsal vertebrae, so that it exceeded that of the lumbar vertebrae.

In the absence of sufficient clinical data to warrant the diagnosis of acromegaly in this instance, it would seem that in hypertrophic pulmonary osteo-arthropathy one may occasionally see changes in the vertebral bodies similar to those described in acromegaly.

SUMMARY

Roentgen studies of the vertebral columns of patients with long-standing, advanced acromegaly frequently reveal characteristic changes in the bodies of the vertebrae and in the adjacent intervertebral discs. In addition, there is often a specific spondylitis.

The vertebral columns of patients with hypertrophic pulmonary osteo-arthropathy were similarly examined. The findings are presented.

REFERENCES

1. Arnold, J. Weitere Beiträge zur Akromegaliefrage. *Arch. f. path. Anat.*, 1894, *135*, 1–78.
2. Atkinson, F. R. B. Acromegaly, from study of literature 1931–1934. *Endokrinologie*, 1936, *17*, 308–320.
3. Brigidi and Broco. Quoted by Schmidt, M. B. in: Henke, F., and Lubarsch, O., editors. Handbuch der speziellen pathologischen Anatomie und Histologie. Vol. IV. J. Springer, Berlin, 1937.

4. Curschmann, H. Ueber regressive Knochenveränderungen bei Akromegalie. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1905–1906, *9*, 83–92.
5. Cushing, H., and Davidoff, L. M. Pathological Findings in Four Autopsied Cases of Acromegaly, with Discussion of Their Significance. Monographs of the Rockefeller Institute for Medical Research, No. 22, 1927.
6. Dietrich, A. Knochen- und Gelenkveränderungen bei Akromegalie. *Verhandl. f. deutsch. path. Gesellsch.*, 1909, 78–85.
7. Erdheim, J. Ueber Wirbelsäulenveränderungen bei Akromegalie. *Virchow's Arch. f. path. Anat.*, 1931, *281*, 197–296.
8. Erdheim, J. Die pathologisch-anatomischen Grundlagen der hypophysären Skelettveränderungen (Zwergwuchs, Typus Frölich, Akromegalie, Riesenwuchs). *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1935, *52*, 234–245.
9. de Langen, C. D., and Zainal. Osseous changes in acromegaly. *Geneesk. tijdschr. v. Nederl.-Indië*, 1932, *72*, 807–809.
10. Marie, P. Sur deux cas d'acromégalie. *Rev. d. méd.*, 1886, *6*, 297–333.
11. Marie, P., and Marinesco, G. Sur l'anatomie pathologique de l'acromégalie. *Arch. de méd. expér. et d'anat. path.*, 1891, *3*, 539–565.
12. Marie, P., and Sanza-Leite, J. D. *New Sydenham Society*, 1890, 180.
13. von Recklinghausen, F. Ueber die Acromegalie. *Arch. f. path. Anat.*, 1890, *119*, 36–53.
14. Sternberg, M. *New Sydenham Society*, 1903.
15. Virchow, R. Ein Fall und ein Skelet von Akromegalie. *Berl. klin. Wchschr.*, 1889, *26*, 81–85.

LOCALIZATION OF INTRAOCULAR FOREIGN BODIES WITH THE CONTACT LENS*

By RAYMOND L. PFEIFFER, M.D., Med.Sc.D.
NEW YORK, NEW YORK

THE localization of intraocular foreign bodies is one of the most exacting procedures which the roentgenologist is called upon to perform. Although many techniques are available, the rather complicated improved method of Sweet is in general use in this country. This method is becoming obsolete in many laboratories, however, because the costly device which it employs is not adaptable to improved or shockproof roentgenographic equipment.

For the past seven years, I have used an entirely adequate and satisfactory technique which employs a minimum of apparatus, and which is easy as well as accurate. This technique gives a meridianal localization, which is the easiest of all for the surgeon to interpret in the operating room.

Comberg in 1927 adapted the Zeiss contact lens to foreign body localization. Prior to this Wessely used a glass prosthesis with tinfoil markers, and later a crystal prosthesis which fitted on the eyeball. These prostheses, however, gave only a clue to the position of the globe, because they did not fit the eye well or follow its movements. Later they were sewed to the conjunctiva, and other disadvantages were thus introduced. Then Engelbrecht designated the cornea by balls of celluloid with wire crosses. These balls answered most requirements successfully. The contact glass of Comberg, in which the limbus of the cornea is designated by lead markers, satisfied the requirements of tight fit and movement. This contact lens is the type used for vision, and if the central vision of the injured eye is not disturbed, it is possible for the eye to fix with this prosthesis in place. An average size lens is used; that is, one with a scleral curve of 12 (12 mm. radius), and a corneal curve of 8 (8 mm. radius). It may be inserted and removed with ease. When sterilized it may be used on a lacerated globe with impunity.

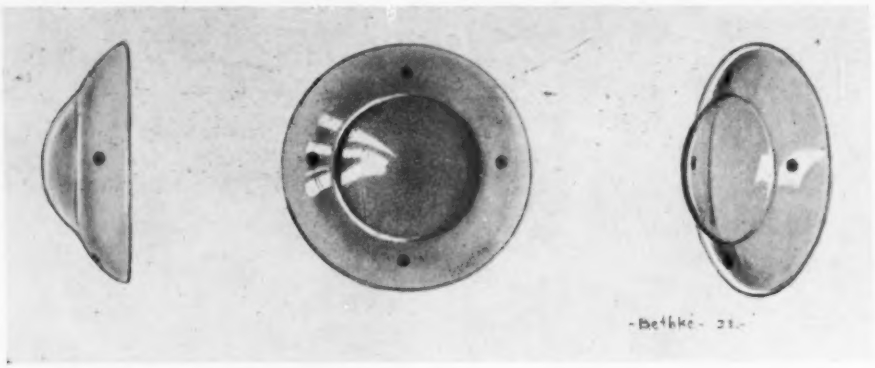


FIG. 1. The contact lens especially adapted with four radiopaque markers for roentgenographic localization of intraocular foreign bodies.

The method to be described is a modification of that of Comberg which employs a contact lens which is fitted on the eyeball under the eyelids (Fig. 1). In practice two exposures are made, a lateral and an anteroposterior. Lines are drawn on the films for measurements to show the relationship of the foreign particle to the contact lens. The measurements are then transferred to a

* From the Department of Ophthalmology, College of Physicians and Surgeons, Columbia University, and the Institute of Ophthalmology, Presbyterian Hospital.

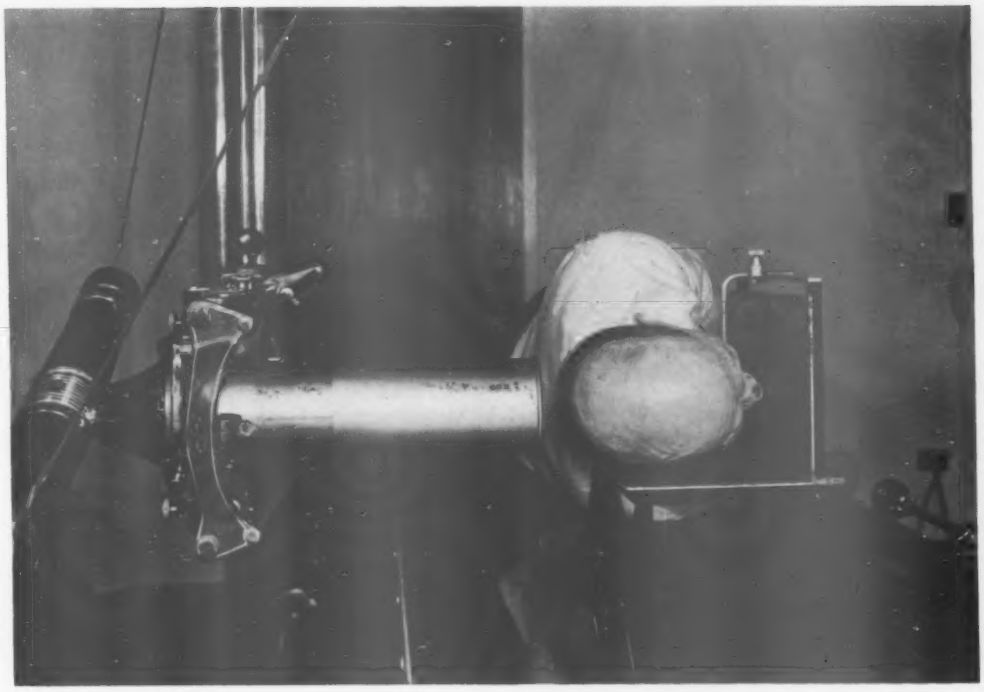


Fig. 2. The arrangement of the apparatus for the posteroanterior film. The patient is in position with the contact lens on the right eye. Note the perfect lateral position of the patient's head with chin and nose against the vertical tunnel. Immobilization is gained through the biting of the bar attached to the device.

chart which represents the anteroposterior view of the eye, and a cross section cut in the meridian in which the body lies (Fig. 5).

In order to shorten the time required for the projections, and also to remove one source of error, I adapted a special device to the technique, which is not, however, indispensable to the method. The device consists of an L-shaped arrangement of tunnels to permit placing the patient's head in one position for both projections. The tube is then shifted for the different exposures (Figs. 2 and 3).

PROCEDURE

The eye containing the intraocular foreign body is anesthetized with several drops of 0.5 per cent solution of pontocaine. The contact lens is then inserted by directing the patient to look down, slipping the glass under the upper lid, and lifting the lower lid. The glass finds its proper position over the cornea. Two exposures or films are made—a posteroanterior and a lateral.

The device is placed on the roentgenographic table and the positions of the tube for the two exposures are determined (Fig. 2). In both positions the primary rays are directed perpendicular to the surfaces of the tunnels so that they pass through the eye containing the foreign body. The exposure for the posteroanterior view is made first. The target-film distance is the same for each exposure, and 35 or 40 inches should be used.

The patient, having a foreign body in the right eye, is instructed to lie on the table on his right side, with the right side of the head on the horizontal tunnel of the device. The tube is aligned in the horizontal position (Fig. 2). The head is placed so that the sagittal plane is horizontal and the injured eye opposite to the lower opening in the vertical tunnel. Through the opening in the vertical tunnel the position of the contact glass on the eye is checked and rotated to place the markers in the vertical and horizontal planes. The patient is asked to gaze directly forward and hold this position. To immobilize the head the

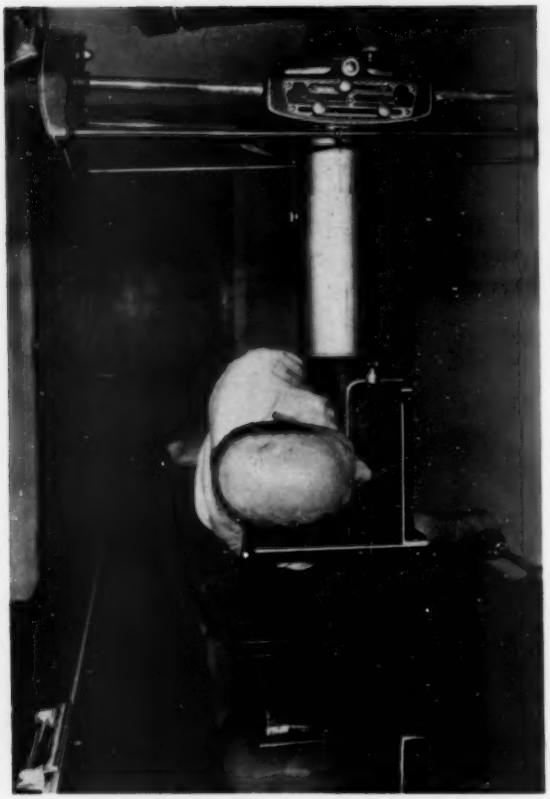


Fig. 3. The arrangement of the apparatus for the right lateral film which is placed in the horizontal tunnel. Note the alignment of the tube for the right orbit. The position of the lens can be checked through the apertures in the vertical tunnel.

patient may bite a bar attached to the device. The position of the tube is checked, the cassette is placed in position in the vertical tunnel, and the exposure is made for the posteroanterior view.

With the patient in the same position, the tube is moved to the vertical position and centered over the patient's eye for the lateral view (Fig. 3). The cassette is placed in the horizontal tunnel under the head, the position of the contact lens is checked, and the second exposure is made. The patient is then permitted to sit in a chair, and after the films are developed the lens is removed. This is done easily by inserting a blunt hook or tooth stick applicator under the lower edge of the lens when the patient is looking up. A special rubber sucker made for inserting and removing the lens may be used.

For localization of a foreign body in the left eye the device is placed at the other end of the table, the patient is made to lie on his left side, and the procedure described above is followed.

Stereoscopic films with head in lateral or Caldwell position might well be made to show the presence of a foreign body before localization is undertaken. Cassettes with fine grain screens are used and the exposures are made slightly less dense than for sinuses.

Bone-free films after the manner of Vogt should be made of every patient with suspected intraocular foreign body. These films are far more sensitive and will reveal small fragments of glass or bodies of almost any density greater than that of the tissues. Minute metallic bodies may be so revealed —bodies which would be lost in ordinary films. Such films are valuable, too, for revealing the exact size and shape of bodies localized in the regular films. It should be pointed out that these films are useful for

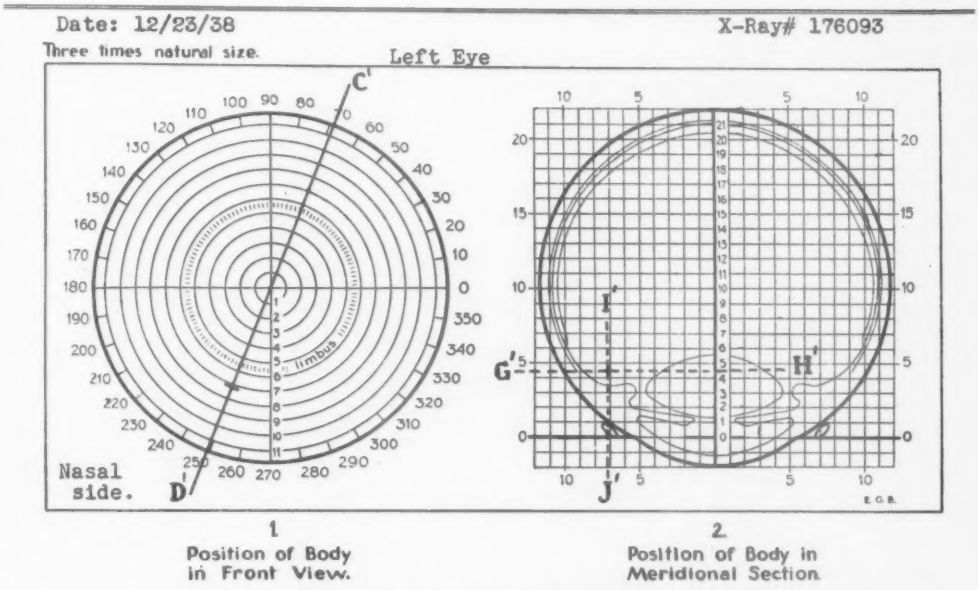
Fig. 4. The posteroanterior film with lines drawn as described in text. The long diagonal line *CD* through the center of the lens and foreign body indicates the meridian in which the body lies. The angle of this meridian is measured with the aid of line *AB* across the orbits.

Fig. 5. The lateral film with lines drawn anterior to the markers to indicate the plane of the limbus *EF*. *GH* passes vertical to *EF* and through the foreign body indicated by arrow.

exploring only the anterior segment of the eyeball and the eyelids.

METHOD OF PLOTTING POSITION OF FOREIGN BODY

With the film of the posteroanterior view in the viewing box, a horizontal line *AB* is drawn or scratched across the orbits several millimeters below the upper margins (Fig. 4). Two lines are then scratched through the markers of the contact lens to locate its center. A longer line *CD* is then drawn to bisect the foreign body and pass through the center of the lens. The angle formed by this line *CD* with the horizontal



Stereoscopic films of the orbits projected in the usual manner revealed the presence of a radiopaque foreign body in the left, apparently within the eye. With the contact lens the body was localized to lie in the 68° meridian (CD), 7.2 mm. (8 mm.-8/10 mm) out from the antero-posterior axis of the eyeball and 4.5 mm. (5 mm. -5/10 mm.) posterior to the plane of the limbus. This position places the particle in the anterior vitreous, overlying the squamous portion of the ciliary body. The fragment is of metallic density and measures approximately ½ x 1 x 2 mm.

Doctor Pfeiffer.
a

Fig. 6. Chart for plotting the localization with typical report. In the meridianal section the position of the body is at the crossing of the lines $I'J'$ and $G'H'$.

line *AB* is measured with a protractor and a corresponding line *C'D'* at this angle is plotted on the chart (Fig. 6). Then, with a compass and millimeter rule, the distance of the foreign particle from the center of the contact glass is measured. This measurement minus a correction factor due to magnified distortion of the film is transferred to the chart and represents the actual distance of the foreign body from the anteroposterior axis of the eyeball. The correction factor depends on several variables in the technique. The contact lens is 20 mm. in diameter and on the film it may measure 22 mm. The error then is one-tenth. Or the actual measurement may be derived from the equation:

size of contact glass: its size on the film = X: film measurement of foreign body from axis of eyeball.

In placing the posteroanterior film in the viewing box for measuring, care should be taken to see that it is viewed as an anteroposterior; i.e., with the right orbit on the left side as though the patient were being examined directly. Then the nasal side of the eye should be carefully labelled on the front view of the chart (Fig. 6). This facilitates interpretation by the surgeon.

The film showing the lateral view is then placed in the viewing box and a line *EF* is drawn across the contact glass, anterior to and tangential to the markers, to locate the limbus of the cornea. A second line *GH* is drawn perpendicular to the first through the foreign body. A measurement is then taken along this second line *GH* from the foreign body to the line of the plane of the limbus. This measurement minus a tenth represents the actual distance of the body posterior to the plane of the limbus and is plotted on the chart in the scheme representing the section of the eyeball. The line *G'H'* is drawn across the section on the chart parallel with the limbus to represent this measurement. A second line *I'J'* is drawn perpendicular to the first to represent the distance of the foreign body from the axis of the eyeball determined in the first plotting. The point of crossing of these two lines is the position of the foreign body in the section of the eyeball in the meridian indicated in the first scheme of the chart. The schemes of the chart are three times normal size for the purpose of accuracy in plotting.

The roentgenologist should be familiar with still another method of foreign body localization which is useful in determining the actual position of a body deep in the eye or orbit. Because of the variation in the size of eyes, methods which locate bodies in relation to the cornea cannot be relied upon entirely when the body is very deep. The question then arises, is the body within the eye or did it come to rest outside of the globe? By injecting air, 4 to 8 cc., into Tenon's capsule through a small needle introduced through the conjunctiva of the lower cul-de-sac at 4:30 o'clock, the posterior segment of the eye can be shown clearly demarcated on films. If films are made with the ray passing tangential to the sclera of the eye opposite the point where the foreign body lies, the question can be definitely decided.

SOURCES OF ERROR

The method of the contact lens is probably the most accurate of all techniques, for the reason that the markers, in relation to which the foreign particle is localized, rest directly on the eyeball and will accurately indicate the position of the eye. Accuracy is gained, too, by using the plane of the limbus rather than the apex of the cornea, as the point of relation of the structures of the eye to the foreign body. The two films reveal all the information needed for the plotting and it is scarcely possible to make a sizable error. From them one can tell whether or not the procedure was performed correctly. Chance superimposition of the foreign particle by a marker of the contact lens in the posteroanterior film need not mislead, for the relationship is revealed in the lateral film. Objections to the use of screens scarcely apply to the present day fine grain screens which give excellent detail. Nothing is to be gained by using film holders.

There is, however, one source of error which may prove disconcerting. It is quite apparent that one contact lens will not fit all eyes, since eyeballs vary much in size and curvatures. A lens of average size is used and fair fitting is usually attained. Frequently there is a tendency for the lens to gravitate downward and thus leave the curves of the cornea and sclera. If this happens it should be noted, and the degree of slipping estimated and allowed for. The lens may be held in position, however, by the rubber end of a pencil, or by a piece of thread, the end of which is affixed to it with scotch tape.

The primary pencil of rays should pass through the eyeball and be perpendicular to the film. Care should be exercised then in positioning the tube for the exposures. The patient's head should be placed accurately on the device with the chin against the vertical tunnel and the forehead approximately 2 inches away from it to approximate the Caldwell position on the film. (Note position of orbital structures on the posteroanterior film, Fig. 4.) The patient should be carefully instructed to gaze directly forward and not move eyes or head during the exposures.

The measurements for the plotting should be taken with a compass from lines accurately scratched on the films. The axis of the meridian in which the body lies should be taken with a transparent protractor.

CONCLUSION

A method for the roentgenographic localization of radiopaque intraocular foreign bodies is described. The advantages of this method are accuracy, simplicity, ease of operation, adaptability, the minimum of apparatus needed, and the meridianal report which it provides. Bone-free films are recommended of all patients suspected of having an intraocular foreign body. The value of injecting air in Tenon's capsule is mentioned.

REFERENCES

1. Comberg, W. Ein neues Verfahren zur Röntgenlokalization am Augapfel. *Arch. f. Ophth.*, 1927, *118*, 175.
2. Comberg, W. Ein Hilfsgerät für mein Verfahren der Röntgenlokalization und einige Bemerkungen über die Technik. *Arch. f. Ophth.*, 1930, *124*, 665–667.
3. Hartmann, Edward. La radiographie en ophtalmologie: Atlas clinique. Masson et Cie, Paris, 1936.
4. Hoffmann, W. Die Röntgendiagnostik und -Therapie in der Augenheilkunde. Radiologische Praktika. Band xix. Georg Thieme, Leipzig, 1932.
5. Spackman, E. W. X-ray diagnosis of double perforation of eyeball after injection of air into the space of Tenon. *Am. J. Ophth.*, 1932, *15*, 1007–1012.
6. Sweet, W. M. The röntgen rays in ophthalmic surgery. *Am. J. M. Sc.*, 1898, *116*, 190–201.
7. Sweet, W. M. Improved apparatus for localizing foreign bodies in eyeball by the roentgen rays. *Tr. Am. Ophth. Soc.*, 1909, *12*, 320–329.
8. Thiel, R. Röntgendiagnostik des Schädels bei Erkrankungen des Auges und seiner Nachbarorgane. J. Springer, Berlin, 1932.
9. Vogt, A. Skelettfreie Röntgenaufnahme des vorderen Bulbsabschnittes. *Schweiz. med. Wchnschr.*, 1921, *2*, 145.
10. Vogt, A. Weitere Beobachtungen über skelettfreie Röntgenaufnahme des vordern Bulbusabschnittes. *Schweiz. med. Wchnschr.*, 1923, *4*, 982.
11. Wessely, K. Verfahren zur Lokalisation von metalischen intraocularen Fremdkörpern im Röntgenbilde. *Ztschr. f. Augenh.*, 1910, *24*.
12. Wessely, K. Ein Verfahren zur Kenntlichmachung der Bulbusoberfläche und der Harnhaut im Röntgenbilde zwecks Lokalisierung von intraokularen Fremdkörpern. *Arch. f. Augenh.*, 1911, *69*, 161–163.

THE COURSE OF BESNIER-BOECK'S DISEASE OF THE LUNGS IN SERIAL ROENTGENOGRAMS*

By EMIL MEISELS
LWÓW, POLAND

IN CONTRAST with the scanty results of clinical observations and examinations are the very conclusive roentgen findings which show intense changes not only in the hilar regions on both sides but also in the lung fields. The most characteristic thing about them is the disproportion between their extent and the subjective condition of the patients, their changeableness and finally their almost complete disappearance in the course of the almost three years of observation.

The first roentgenogram (Fig. 1) in August, 1934, shows a great enlargement of the hilar glands in addition to a slight general darkening of the whole lung picture. On the right the enlarged hilar glands are in oval in shape and about the size of a medium-sized gherkin, on the left they are hemispherical and about the size of a small apple. They are uniformly dense and have sharp, curved outlines. The paratracheal gland is also greatly enlarged and projects into the right subclavicular field in an arched shape. The lung fields at this time do not show any very marked changes. Only the lung outline is somewhat generally increased and from the left hilum lines of increased density pass into the subclavicular field. In the middle fields there are a few small, delicate spots. The diaphragm is at the normal level, is readily movable and normally arched. The angles of the diaphragm are free. This picture did not persist long, however, and only two months later, as shown by the roentgenogram of October, 1934 (Fig. 2) there are marked changes in it. The lung field in general is now clearer. The hilar gland shadows are smaller, less dense and massive. Small clear spots appear in them. The outlines are no longer so sharp and now appear irregularly jagged, especially that of the right hilar shadow. The paratracheal gland is also less homogeneously dense and somewhat clearer. The lung outline of both fields is moderately increased on both sides.

Fig. 1. August, 1934. Large hilar gland tumors on both sides. Great enlargement of the paratracheal gland. Both lung fields show general slight darkening. The lung outline is increased and in the middle fields there are a few small delicate spots.

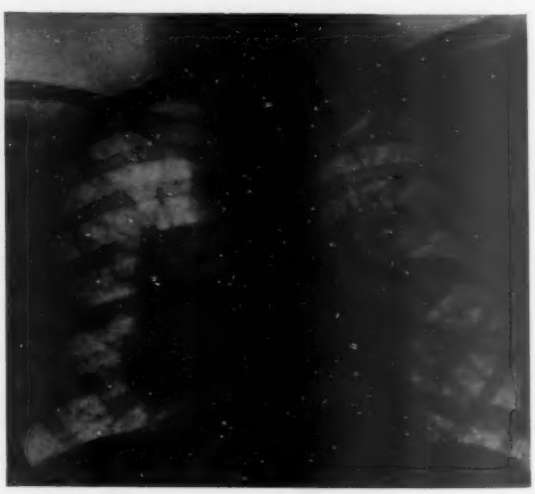


Fig. 2. October, 1934. The lung picture in general is now clearer. The hilar gland shadows are smaller, less dense, and massive, and their outlines irregularly jagged. The lung outline of both lung fields is moderately increased, especially on the left.

* Read at the Fifth International Congress of Radiology, Chicago, Ill., Sept. 13-17, 1937.

In the further course of observation the hilar gland shadows become smaller, flatter and clearer. But at the same time a dissemination of many small spots of increased density, gradually becoming closer together, appears in both lung fields. This is seen most clearly in the roentgenogram of July, 1935 (Fig. 3). The hilar shadows have decreased to a third in size. Their shadows are very unhomogeneous, the outer contours are not sharply defined and are very irregular. This is particularly true of the left hilar shadow. The paratracheal gland also has become distinctly smaller. Both lung fields are occupied by many dense small spots of shadow with soft outlines. These are most numerous in the middle and lower parts of the right lung field, but they are quite numerous also in the apices and in the subclavicular regions. The diaphragm as before shows a smooth outline, is at the normal height and is normally movable. The angles of the diaphragm are free.

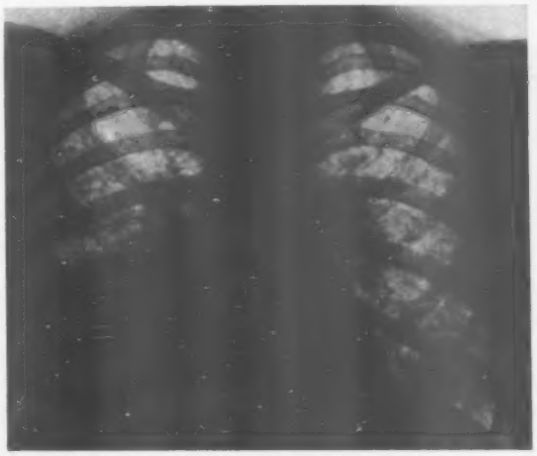


Fig. 3. July, 1935. The hilar glands have decreased to a third in size and are very unhomogeneous. The outlines are indistinct and very irregular. The paratracheal gland has also decreased markedly in size. Both lung fields from the apices to the diaphragm are strewn with numerous, dense, small spots of shadow with soft outlines, which are most closely crowded in the middle and lower parts of the right lung field.

Further changes that take place here are particularly the slow and steady decrease in size and the paling of the small dense spots. They become less intense and are also not so thickly scattered. The outlines which at first were quite soft and indistinct become harder and sharper. As a result of this, the lung fields appear quite gray. The hilar shadows become almost normal in size and density. In Figure 4 (November,

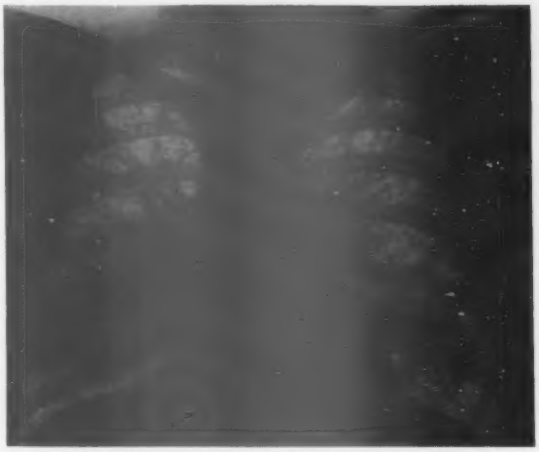


Fig. 4. November, 1935. The small opaque spots with which both lung fields were infiltrated have become markedly paler and harder. But they are as closely crowded as before. The hilar shadows are almost normal in size and density.

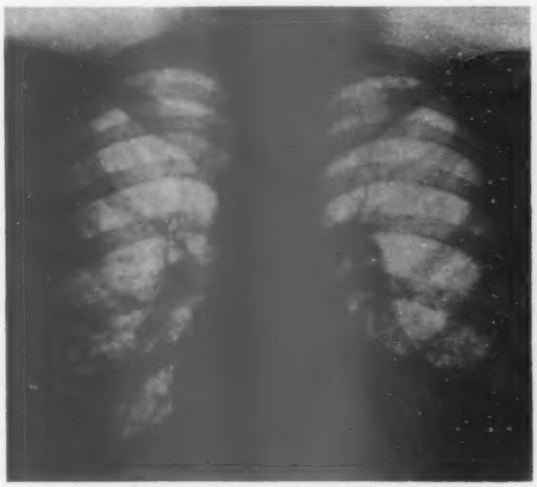


Fig. 5. September, 1936. The upper parts of the lungs are almost normally clear. In the middle and lower parts, particularly marked in the lateral parts of the right middle field, there is now a delicate reticular opacity with indistinct outlines. In the hilar shadows a few small, rounded calcium foci are visible.

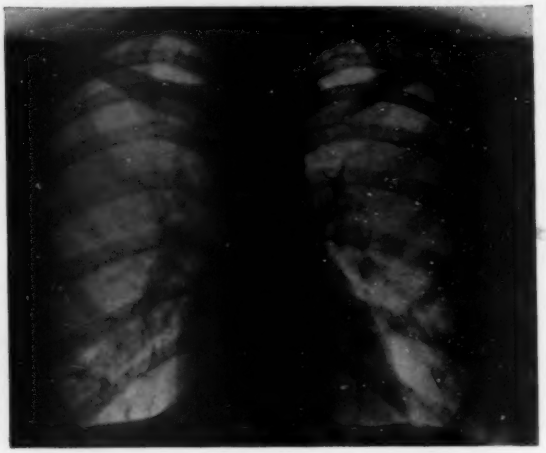


Fig. 6, December, 1936. Normally clear lung fields except for remnants of a very delicate reticular shadow in the lower and lateral parts of the right lung field, of which a trace can also be seen in the lower lateral parts of the left lung field.

1935), the small dense spots with which both lung fields are infiltrated are markedly paler and harder than three months before. They are about as closely grouped as they were before.

Later the small dense spots become constantly more delicate and less dense. This is particularly true of the upper parts which slowly attain normal clearness. In the roentgenogram of September, 1936 (Fig. 5), the clearness of the upper lung fields is also almost normal. The small dense spots have entirely withdrawn from these parts. In the middle and lower parts they still remain to some extent and here form a rather delicate reticulate shadow with indistinct outlines which is especially marked in the lateral parts of the right middle field. A few small, rounded foci of calcification appear in the hilar shadows. The roentgenogram of December, 1936 (Fig. 6), shows only remnants of a very delicate, reticulate shadow in the lower and lateral parts of the right lung field, a trace of which can also be seen in the lower lateral parts of the left lung field; the rest of the lung fields is normally clear. In this case distinct metamorphoses therefore appeared in the course of two years in the visible roentgen changes in the hila and lung fields. At first we had large hilum gland masses and the changes in the lungs themselves at this time were rather slight. Slowly the gland tumors grew smaller, probably as a result of irradiations given the patient in the spring of 1935 by Dr. Blubaum of Cracow, until finally two years later they have disappeared entirely. But at the same time a dense and almost uniformly distributed dissemination of small spots of density appeared in both lung fields. These opacities, at first soft and intense, gradually became harder and paler until finally in the course of two years they have disappeared almost completely.

The changes in neither the hila nor the lung fields are in themselves characteristic. The large hilar tumors at first suggest lymphogranulomatosis, lymphosarcoma or leukemic gland tumors. But these diseases could easily be excluded by clinical examination and observation.

Differential diagnosis from tuberculosis was much more difficult, particularly from the disseminated forms with a mild course. Such cases of "benign forms of miliary tuberculosis" have often been described recently, thanks to roentgen observation. The very chronic and markedly benign course, absence of disintegration of tissue and calcification, no transition into caseation and the complete retrogression due only in part to irradiation (of the hilar glands) and the lack of further appearance of tuberculous foci in other organs, are therefore quite characteristic but not sufficient for diagnosis. The rapidity with which the metamorphoses in the lung changes occur is also unusual. But this also is not sufficiently decisive for differential diagnosis. We are therefore obliged to base the differential diagnosis on the results of clinical examination and the outcome of biological reactions. In our case, the repeatedly negative outcome of biological reactions and the whole clinical course could not, as shown more in detail above, be reconciled with a tuberculous causation of the disease, and forced us to make a diagnosis of Besnier-Boeck's disease, which is similar in roentgenograms to tuberculosis

but is a fundamentally different disease. The diagnosis was rendered more difficult in our case because there were no skin manifestations. But cases are known in the literature which were verified by autopsy in which only the lungs and other internal organs were affected but no changes could be demonstrated in the skin. The lack of these characteristic changes therefore cannot be used against the diagnosis.

The first descriptions of the lung changes were given by Schaumann and were published as late as 1914. In 1915 they were described by Bittorf and Kuznitzky and further cases were published by Kirklin, Morton, Assmann, Pautrier, Nielsen, Saacke and other observers. The two kinds of lung changes described by Schaumann and Pautrier were: (1) a symmetrical dissemination of opaque foci which were said to be similar to the metastases of a leukemia (?), and (2) fibroid peribronchitic infiltrations with enlarged hilar glands and perihilar shadows. Gadrat and Marqués, who have recently described cases, found a third form which was similar to a caseous fibrinous pulmonary tuberculosis. This classification seems to us a little too narrowly conceived because they do not take into consideration the metamorphoses which occur in the lung changes, which were very distinct in our case. But all authors, including those last-named above, note the very chronic and benign course and the chiefly productive-proliferating character of the lung changes, the fact that they recede completely and the lack of clinical symptoms, because of which the cases cannot be recognized on simple examination. These characteristics were noted in our case also.

As to the frequency of the changes in the lungs and the tracheobronchial glands in Besnier-Boeck's disease, they are by no means rare. Martenstein describes them in 45 cases, Kissmayer found them in 19 out of 24 cases observed. Other authors, including Pautrier and Nielsen, found them in similar proportions. This quite frequent occurrence of such lung changes, as shown by the statistics cited, suggests the possibility that the cases which occur with the picture of pronounced disseminated lung tuberculoses with a mild course, which are described by many authors (Boedecker, Martenstein) as pulmonary tuberculids are in reality cases of Besnier-Boeck's disease. The cases described in the literature seem to us to justify this assumption.

THE ROENTGEN RAY IN OBSTETRICAL DIAGNOSIS*

By SAMUEL GEORGE SCHENCK, M.D.
BROOKLYN, NEW YORK

THE progress of obstetrical roentgenology in the past decade has been so rapid and significant that it is well to pause, if only for a moment, to review and emphasize the more worthy attainments and procedures. It is therefore our purpose to gather together the recent contributions of roentgenology in obstetrical diagnosis with the hope that, although few additions can be made to the already imposing list, we may at least indicate the more pertinent accomplishments and urge a freer use of the possibilities of roentgenologic assistance in solving many obstetrical problems.

MATERNAL PELVIS

The recent work of Caldwell, Moloy and D'Esopo[4,5,6] in describing the four parent types of female pelves and their variations as well as their roentgen studies of the mechanism of labor has changed many old conceptions. The normal variations of the pelvis as described by these investigators consist of the four primary types: the anthropoid (ape), the gynecoid (female), the android (male) and the platypelloid (flat). Not infrequently, however, the female pelvis shows a mixed type, such as an anthropoid type with gynecoid tendency, or a gynecoid type with anthropoid tendency, etc. These mixed types can best be detected in stereoscopic films. A careful perusal of the papers of Caldwell, Moloy and D'Esopo by roentgenologists as well as obstetricians will throw a new light on the subject. The true configuration of the maternal pelvis can only be obtained by the roentgen examination.

FIG. 1. Nägele pelvis, showing the shortening of the sacral alae on the left and the resultant pelvic asymmetry.

The abnormal variations of the female pelvis are divided into two groups, the congenital and the acquired. In order to obtain accurate information from the films, the pelvis must be "opened" so that the inlet lies in a plane parallel to the film. Stereoscopic roentgenograms are also of material assistance.

Among the congenital malformations may be mentioned the Nägele pelvis which shows an absence or a shortening of one of the sacral alae (Fig. 1), the Roberts pelvis characterized by an absence of the alae of the sacrum, the high assimilation pelvis with six sacral segments, the low assimilation pelvis with only four sacral vertebrae, the Otto pelvis which reveals an intrusion of the femoral heads and acetabula into the pelvic canal, and other rarer anomalies.

Acquired deformities of the pelvis may be the result of infantile or late rickets, osteomalacia (Fig. 2), spinal curvature, os-

FIG. 2. Advanced osteomalacia of the female pelvis.

teodystrophies, tuberculosis, syphilis, hip joint diseases and injuries. Old fractures of the pelvis and femur, especially with poor end-results, often result in pronounced pelvic asymmetry.

Jacobs[10] points out the importance of the roentgen study of the inclination of the pelvic inlet and outlet, which have a decided influence upon the mechanism of labor. Matthews[16] mentions the possibility of diagnosing the presence of tumors of the bone, uterus or ovary, with or without pregnancy, as another advantage of the roentgen examination.

DIAGNOSIS OF PREGNANCY

In the first four months, the diagnosis of pregnancy by the roentgen ray is unreliable in the majority of cases, except by special methods which are not without danger to the growing ovum. Occasionally the fetal skeleton can be detected as early as three and a half months in plain films. However, such a demonstration is the exception (occurring in about 15 per cent of the patients) and depends largely on the maternal build and excellent technique. Special methods such as Peterson's[20] air insufflation into the pelvic peritoneum by the transuterine route revealing the outline of the enlarged uterus and the injection of iodized oil into the uterine canal for demonstrating the filling defect produced by the embryo may be hazardous. Now, with the Aschheim-Zondek and the Friedman test positive in 98 per cent of the cases, special roentgen procedures for the early diagnosis of pregnancy are usually unnecessary.

However, there are occasions when the diagnosis of an extrauterine pregnancy is suspected and further confirmation is desired. In such cases, the careful instillation of iodized oil into the uterus demonstrates the absence of a filling defect normally produced by an intrauterine gestation. Of course, the danger of abortion in cases in which the clinical diagnosis is in error and the embryo is found in the uterus after uterography must be considered, although I have performed lipiodol studies in several cases of intrauterine pregnancy with no untoward results.

Mathieu[15] describes the roentgen findings in two types of tubal pregnancy after iodized oil instillation which, with the proper technique, he considers harmless. In the first type with the embryo located at the fimbriated end of the tube, the oil surrounds the ectopic mass in characteristic fashion. In the second type with the pregnancy in the midportion of the tube, the oil is completely blocked so that it ends abruptly in a rounded manner at the ectopic mass, which completely seals off the tube at this point and is therefore not outlined by the opaque medium. This finding is the same in ruptured or unruptured ectopic pregnancies. When the clinical diagnosis is in doubt, Mathieu finds that hysterosalpingography is a valuable procedure in the diagnosis and localization of an ectopic gestation.

In the second half of pregnancy anteroposterior and lateral films will demonstrate the presence of the fetus in 100 per cent of the patients. The roentgen visualization of fetal parts is an absolute sign of pregnancy. A definite diagnosis of pseudocyesis is also possible after the fifth month. Roentgenography is invaluable in the diagnosis of single or multiple gestation. In the latter months the presentation and position of fetus and the presence or absence of engagement can be ascertained from the films. The roentgen ray may establish or confirm the diagnosis of an abdominal pregnancy, thus fortifying the physician with the advanced knowledge of a surgical termination. The recognition of a lithopedion is usually possible only by roentgenography.

The roentgen ray is of material aid in the differentiation of ovarian tumors, uterine fibroids, calcified or not, and hydatidiform moles from pregnancy. The possibility of a coexisting gestation in a patient with a pelvic tumor must always be borne in mind and carefully searched for. A barium filled bowel will often assist not only in the recognition but also in outlining the upper limits of these tumors which arise from the pelvis

and displace the bowel upward. The roentgenogram of the air-filled colon (Bastedo's air insufflation of the bowel) will often serve the same purpose. When a tumor of the uterus, such as a fibroid of at least moderate size, complicates pregnancy, the fetal skeleton appears smaller than would be expected from the size of the soft tissue shadow cast by the growth. Depending on its bulk, the tumor may also displace the fetus. The nodular outline of the fibromyomatous uterus not infrequently can be visualized in the roentgenogram.

In the latter months of pregnancy the films show a widening of the pelvic joints, particularly the symphysis pubis, which is probably due to softening and relaxation of the ligaments preparatory to labor.

FETAL AGE AND MATURITY

Clinically, fetal age is determined by the menstrual history and by the height of the uterine fundus. There are instances in which such information may be vague and misleading, and roentgenology has endeavored to find a more accurate solution of this problem. Several methods have presented themselves: (1) the estimation of fetal age by the appearance of the ossification centers; (2) the fetal age determination from the length of the fetal skeleton; (3) the estimation of the month of pregnancy or fetal age from the corrected fetal fronto-occipital diameter.

Adair and Scammon[1], and others[17,22], have studied the time of ossification of the epiphyses of the fetus, particularly at birth, and from their results have determined the maturity of the newborn. Most investigators agree that the distal femoral epiphysis, which begins to ossify in the last month of gestation, is roentgenologically visible at birth in 99 per cent of infants. This finding prompted Köhler[14] to consider the presence of the osseous nucleus of the distal femoral epiphysis as the surest sign of maturity, syphilis appearing to be the only cause for its delay. This ossification center, therefore, assumes medicolegal importance in determining the maturity of the child.

Yet, when one must determine the age of the intrauterine fetus, the appearance of the ossific nuclei is not a reliable criterion. Many factors may produce marked variations in epiphyseal development, such as heredity, endocrine disorders, nutrition, infection, sex, etc. There is a noticeable lack of unanimity in the time of appearance of many epiphyseal centers as given by many investigators, whose work has been done on laboratory material rather than on the fetus in utero. Lastly, there are evident technical difficulties encountered in the accurate visualization of the various centers of ossification in the roentgenograms of the average pregnant patient.

The second method for the determination of fetal age is made from the crown-heel length of the fetus corrected for distortion and estimated from the equation published by Scammon and Calkins[23]:

$$L = 28\sqrt{T - 0.74} - 35$$

in which L = crown-heel length of the fetus in cm. and T = fetal age in lunar months.

Haase's[8] rule has the advantages of simplicity: Fetal length in centimeters = (age in months)^2 before the fifth month of gestation; fetal length in centimeters = age in months $\times 5$ after the fifth month.

Probably a more accurate estimation can be made by using the fronto-occipital diameter of the fetal skull. Thoms[28,29] and Walton[32,33,34] determine the true fronto-occipital diameter from the magnified diameter in the film with the following formula:

$$O = X\frac{D - Y}{D}$$

in which O = true fronto-occipital dimension of the fetal skull if same lies parallel to the surface of the film; X = magnified fronto-occipital diameter in the film; D = target-film distance; and Y = perpendicular distance from the center of the fetal fronto-occipital diameter to the surface of the film. This formula is derived from the simple algebraic equation of right angle triangles which are directly proportional to each other.

If Y is approximately 7 inches (Schnitker, Hodges and Whitacre)[24] or 15 cm. (Thoms, Walton), the true fetal fronto-occipital diameter is readily calculated, provided it can be visualized in the film and lies approximately parallel to the film. This diameter is 20 per cent less than the distorted image in the film. Therefore, if the magnified fronto-occipital measurement is multiplied by 0.8, assuming a 20 per cent distortion due to magnification by the cone of rays, the true fetal fronto-occipital diameter is readily estimated. Similarly, the correction is made for the distorted length of the fetus, if this measurement is to be used in calculating the fetal age.

Schnitker, Hodges and Whitacre modified Scammon and Calkin's formula by combining the fronto-occipital diameter with the crown-heel length to read in centimeters and in calendar months. These revisions were converted into a graph (Fig. 3), from which the probable fetal age can be readily obtained when the corrected fronto-occipital diameter in centimeters is known. Although there is some discrepancy in the later months of pregnancy between the minimum and maximum age for a particular diameter, the method is not without merit and presents a graphic method of estimating the approximate age of the fetus in utero.

FETAL DEATH

The criteria for the roentgen demonstration of missed abortion or fetal death are overlapping of the bones of the skull (Spalding's sign)[25], lordosis of the caudal half of the fetal spine (Jungman's sign)[13] or angulation of the spine, collapse of the thorax (Matthews' sign)[16], faint visualization of the fetal shadow or fetal decalcification, and disproportion between the size of the fetus and the duration of pregnancy.

Overlapping of the bones of the fetal skull (Fig. 5) with asymmetry of the head is due to maceration and shrinkage of the brain as a result of postmortem changes. It cannot be distinguished from the overriding observed in labor or in engagement when the head molds or from pseudo-overlapping due to superimposed shadows which may resemble those of sutures and fontanelles. The latter source of error may be avoided by re-examination or by stereoscopic views in the semi-recumbent position.

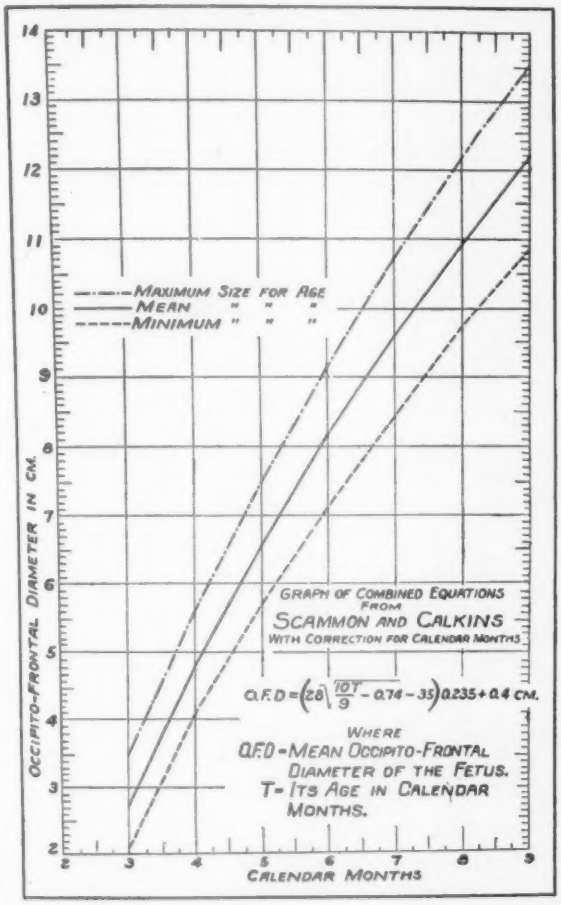

OCCIPITO-FRONTAL DIAMETER IN CM.
CALENDAR MONTHS
MAXIMUM SIZE FOR AGE
MEAN " " "
MINIMUM " " "
GRAPH OF COMBINED EQUATIONS FROM SCAMMON AND CALKINS WITH CORRECTION FOR CALENDAR MONTHS
O.F.D = (2.8 √(10T/9) − 0.74 − 3.5) 0.235 + 0.4 CM.
WHERE
O.F.D = MEAN OCCIPITO-FRONTAL DIAMETER OF THE FETUS.
T = ITS AGE IN CALENDAR MONTHS.

Fig. 3. Combined graph for estimating fetal age in calendar months from the fronto-occipital diameter of the fetal skull in centimeters (after Schnitker, Hodges and Whitacre).

Overlapping of the skull bones may be observed within a week after fetal death. Excellent technique and multiple views are of great help. Schnitker, Hodges and Whitacre mention three factors which may prevent the appearance of this criterion in a particular dead fetus: (1) hydrocephalus; (2) poor visualization due to the faint shadow of the fetus or to overlapping shadows

Fig. 4. Fetal death. Gestation, seven months. Estimated fetal age, five months. Breech presentation. Note the ribs in the region of the fetal abdomen and lumbar spine due to maceration; yet there is an absence of asymmetry and overlapping of the bones of the fetal skull. Anterior hysterotomy confirmed the diagnosis of a well-macerated fetus with its thoracic cage detached from the spine and occupying the lowermost position in the sac.

of the maternal pelvis, intestinal gas, etc.; re-examination may help; (3) the time factor. The exact time interval between death of the fetus and the appearance of overlapping is not known, so that roentgen examination in the interim may not show this sign although the fetus may be dead.

I have never seen the roentgen appearance of wrinkling of the forehead occasionally mentioned as a sign of maceration or fetal death.

Angulation of some part of the fetal spine which may assume a U-shaped concavity is another criterion of fetal death. This sign may occur, however, in a live single fetus, particularly during labor, and is often present in twins (due to overcrowding).

Collapse of the thoracic cage, due to maceration, may occur. Roentgenologically, it is shown by the irregular narrowing of the fetal intercostal spaces and in well macerated fetuses by an overlapping of one or more ribs.

In well advanced maceration, the costal cage may detach itself from the spine and assume a more dependent position in the fetal sac. This phenomenon occurred in one case (Fig. 4) in which the estimated duration of fetal death was two months. The roentgenograms showed a breech presentation with the ribs entirely detached en masse from the thoracic spine and lying in the region of the fetal abdomen and pelvis. The finding was confirmed after the sac was removed intact and its contents examined.

The faint visualization of the fetal bones, first described by Portes and Blanche,[21] is believed by them and subsequently by others to be due to a decalcification of the dead fetal skeleton. Many investigators doubt that a decalcifying process takes place after death. Lithopedions retain their calcium for months and years. Schnitker, *et al.*, therefore, prefer to use the term

Fig. 5. Intra-uterine gas-forming infection as shown by the free gas in the uterine cavity (*G*). Note the gas-filled intestine (*I*) displaced upward by the enlarged uterus, and the overlapping of the bones of the fetal skull indicative of maceration (a sign of fetal death).

"faint shadow" to describe the indistinctness of the bones of the dead fetus, and point out that this sign at best is unreliable because of the possibility of technical errors such as overpenetration and motion, and of the presence of excessive fluid as in polyhydramnios.

A valuable criterion of fetal death, first described by Tengbergen[26] and Henrotay[9], is the disproportion between the size of the fetus and the estimated month of pregnancy. A graphic method for determining the approximate age of the fetus has already been described. However, it is more accurate to add 1 cm. to the actual fronto-occipital diameter for overlapping of the skull bones, if present.

Free gas in the amniotic sac signifies fetal death with secondary infection from a gas-forming organism (Fig. 5).

Of these signs of fetal death one or more may be present. It is the exception rather than the rule to demonstrate all of the criteria in any particular case. A positive sign of life is blurring of the shadow of one of the fetal extremities indicating motion (Fig. 6).

Fig. 6. Lateral projection of intra-uterine fetus showing a blurring of the shadow of the upper extremity (arrow) indicating motion during the roentgen exposure. This is a positive sign of fetal life, provided there has been a complete cessation of breathing and motion of the mother during the exposure.

PLACENTA PRAEVIA

Roentgenography offers a simple and harmless method of diagnosing placenta praevia. By establishing the presence of placenta praevia, an accidental hemorrhage from a premature separation of a normally located placenta can be excluded and at the same time the type of placenta praevia, whether central or marginal, can be detected. It is generally recognized that vaginal examinations are not without danger in the final month of pregnancy, particularly when there exists a possibility of terminating the gestation by cesarean section.

Menees, Miller and Holly[18] have performed amniography for the purpose of locating the placental site by injecting 10 cc. of strontium iodide through the abdominal and uterine walls directly into the amniotic sac. The amniotic fluid is thus rendered opaque and the placenta appears as a filling defect or a flattened area best seen in the oblique view. The danger of this method lies in the possibility of injecting into the placenta, resulting in the premature onset of labor.

Recently the cystogram method of diagnosing placenta praevia was described by Ude and Urner.[31] Forty cubic centimeters of a 10 per cent sodium iodide solution are injected into the empty urinary bladder through an ordinary catheter, following which the patient is roentgenographed in the anteroposterior and oblique positions with the central ray directed vertically over the lower abdomen.

Interpretation of the roentgenograms depends on the relation of the fetal head to the urinary bladder. As a rule, the lower uterine segment in the last trimester of pregnancy contains one pole of the fetus. In the cephalic presentation the head of the fetus will normally rest against the posterosuperior surface of the bladder displacing the intestines and omentum superiorly and posteriorly. In this relationship the bladder shadow will show as a crescent-shaped mass and will approximate the head of the

Fig. 7. *A*, anteroposterior projection showing the wide space between the dye-filled bladder and the fetal skull. The outline of the placenta can be faintly seen (arrows). Diagnosis: placenta praevia centralis. Confirmed by cesarean section. *B*, same patient in the lateral position.

fetus. The narrow space between the radiopaque bladder and the fetal skull scarcely exceeds 1 cm., and represents the thickness of the fetal scalp, the lower uterine segment (which measures only a few millimeters in thickness), peritoneum and the thin bladder wall.

When the placenta rests in the lower uterine segment, the space between the fetal skull and bladder is materially increased by the thickness of the placenta. The width of the space may be 2 cm. or more in the film. If the width is almost uniform throughout the expanse of the bladder, the finding represents a placenta praevia centralis (Fig. 7). However, in placenta praevia marginalis, the increased width of the space between the skull and bladder is only observed laterally (Fig. 10*B*). In excellent roentgenograms it is sometimes possible to visualize the soft tissue shadow of the placenta (Fig. 7*A*).

In place of the sodium iodide solution any of the other contrast media used in obtaining cystograms may be substituted. I have also been successful in visualizing the relation between the fetus and dye-filled bladder in excretion urography.

The cystogram can be made without danger of provoking hemorrhage or introducing infection. The roentgen diagnosis corroborated by the clinical findings is accurate in a very high percentage of cases.

FETAL ABNORMALITIES

The importance of the diagnosis of intra-uterine fetal malformations and monstrosities is self-evident and the roentgen examination is the most reliable means at our disposal to detect such abnormalities before delivery. Malformations such as anencephalus (Fig. 8) and microcephalus are best demonstrable in the films. Hydrocephalus (Fig. 9) is revealed by the large skull and gaping fontanelles. Extensive spina bifida can also be detected. Among other pathological conditions, intra-uterine fetal rickets, achondroplasia, syphilis and fractures have been demonstrated, and in one instance I have been able to diagnose marble

bones (Albers-Schönberg's disease) of the fetus in utero by the unusual density of the skeletal structures (Fig. 10). Matthews emphasized the importance of roentgenographing every patient for whom cesarean section is contemplated to avoid the embarrassment of delivering a fetal monstrosity.

The diagnosis of a polyhydramnios, which often accompanies fetal abnormalities, is possible by the poor visualization of the fetal bones notwithstanding careful and accurate technique. The excessive fluid in the amniotic sac prevents a sharp shadow of the skeletal structures.

EXTRA-PELVIC DISORDERS

The customary use of the roentgen rays in medical and surgical conditions is too well known to require more than mere mention. Particular attention is called, however, to the information acquired by intravenous and retrograde pyelograms in observing physiologic and pathologic changes in the urinary tract incident to pregnancy.

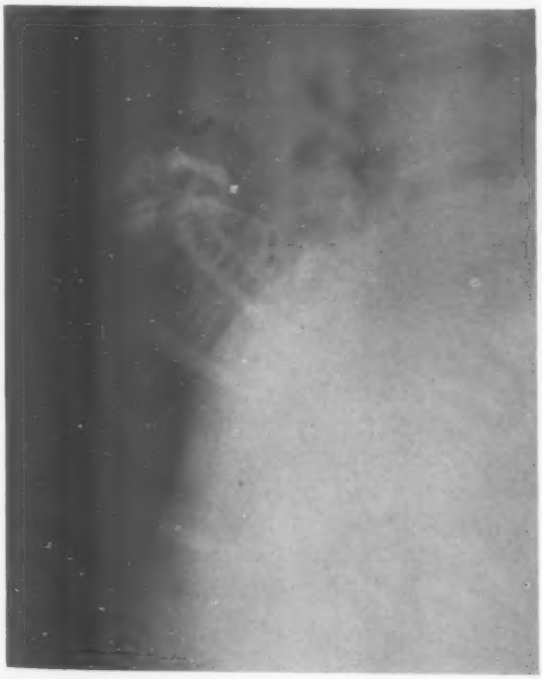


Fig. 8. Anencephaly (arrow) in the lateral projection just before delivery. Breech presentation.

Fig. 9. Tremendous hydrocephalus of an intrauterine fetus immediately before surgical delivery.

PELVICEPHALOMETRY

Roentgen measurements of the pelvis and fetus are responsible to a large degree for the recent interest in the invaluable possibilities of roentgenography in obstetrical diagnosis. With methods of computing accurately the volume of the fetal skull and the diameters and volume of the birth canal, the day of guessing at the possibility of disproportion simply by contemplating the magnified shadows in the roentgenograms is past. Space will not permit a detailed discussion of the various methods in use, but it lies within the scope of this paper at least to mention the four more commonly used techniques: the Thoms method, Ball's technique, Johnson's stereoroentgenometer and Molloy's precision stereoscope.

Thoms[27,30] places the patient in the semirecumbent position so that the inlet lies approximately parallel to the film. After the pelvis is exposed to the rays, the patient is

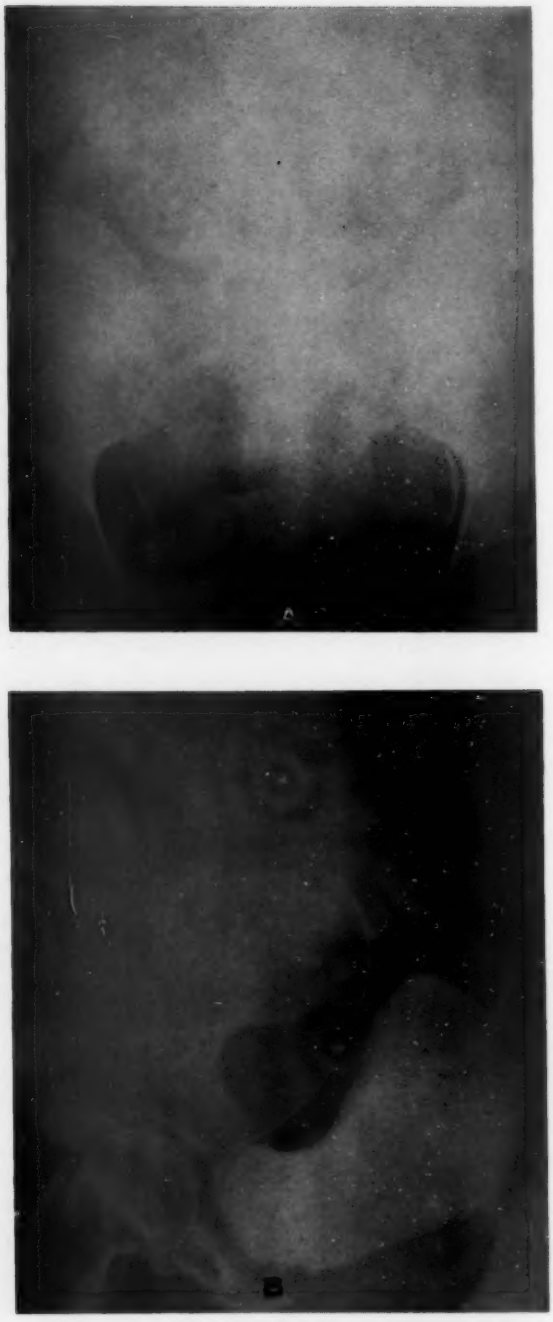


Fig. 10. *A*, the generalized haziness, which partially obscures the maternal spine yet shows the fetal spine more or less distinctly, suggested the diagnosis of polyhydramnios with marble bones (Albers-Schönberg's disease) of the fetus. The large fetal skull for the estimated gestation of seven months indicates a hydrocephalus. *B*, lateral view of the same patient after cystography. The increased space between the bladder and skull laterally indicates a marginal implantation of the placenta.

removed and on the same film a flash exposure of a grid with perforations 1 cm. apart is made. The holes of the grid are seen in the film as small black spots from which distortion of the pelvic diameters is corrected. Similarly, with the patient supine, the true fronto-occipital diameter of the fetal skull is obtained, assuming that this diameter lies approximately in the transverse diameter of the maternal pelvis, which in most instances is true. From this measurement the biparietal diameter and the weight and length (crown to heel diameter) of the fetus are calculated.

Walton[32,33,34] employs the Thoms technique except that he uses a "false centimeter scale" in place of the grid. His calculations are readily read off the chart. Friedman's[7] table further simplifies the "false centimeter scale" of Walton.

Ball[2,3] devised an ingenious tracer which he calls a pelvicephalometer, with which he calculates the volume of the fetal skull and the volume of the pelvic canal in its smallest portion estimating the smaller pelvic measurements, namely the true conjugate and the bisischial diameter. The patient lies supine and the pelvis is roentgenographed in the anteroposterior and lateral positions with the central ray focussed at the level of the iliac crests. Correction is made for the thickness of the scalp and molding of the head.

In Johnson's[11,12] method two stereoscopic views are taken with careful centering and shifting of the tube. Identical landmarks are located on both films. They are then placed in a special stereoscope, the stereoroentgenometer, and, by means of two threads, the true conjugate and other pelvic diameters, as well as those of the fetal skull, are measured.

Moloy[19] employs the physical principle that stereoscopic images, under proper conditions, can be measured directly in space

Postmortem findings: Polyhydramnios, lateral implantation of the placenta, fetal prematurity and hydrocephalus, Albers-Schönberg's disease of the fetus.

by movable armatures equipped with points which can be placed on any bony prominence. A metal bar containing a perforation near either end is placed on the cassettes, the midpart of the bar opposite the geometric center of the film and along the film edge. Stereoscopic views of the patient are then taken at a 25 in. tube-film distance with a 2½ in. target shift. The stereoscopic image projected into space represents a true optical view.

Although these methods of roentgen computation of obstetrical mensuration represent a decided advance in precision and accuracy, no one technique is sufficiently ideal to have demonstrated its superiority over the other methods. However, constant improvements in simplicity and accuracy are being made, and the day is not far distant when in place of four or more procedures there will be one technique which will give the exact numerical information. In fact, today no obstetrician can afford to rely solely on his clinical methods in a suspected case of disproportion between the passage and the passenger without resorting to roentgen mensuration.

SUMMARY AND CONCLUSIONS

An attempt has been made to indicate the advances of the roentgen examination in obstetrical diagnosis and its help in solving certain pressing problems. Roentgenography has been particularly useful in the recognition of the type and configuration of the maternal pelvis, in the diagnosis of pregnancy, multiple fetuses, monstrosities, fetal aberration and fetal death, in the estimation of fetal age and maturity, in the diagnosis of placenta praevia and extrauterine pregnancy, and in the recognition of pelvic tumors whether or not associated with pregnancy. Finally, the generally employed methods of pelvimetry and fetometry have been indicated.

The roentgenologist can offer material aid to the obstetrician. With a spirit of close cooperation between these specialists, roentgenology will soon reach the important position in obstetrics which it now holds in surgery, medicine and other specialties.

REFERENCES

1. Adair, F. L., and Scammon, R. E. Study of ossification centers of wrist, knee and ankle at birth, with particular reference to physical development and maturity of newborn. *Am. J. Obst. & Gynec.*, 1921, *2*, 35–60.
2. Ball, R. P. Roentgen pelvimetry and fetal cephalometry. *Surg., Gynec. & Obst.*, 1936, *62*, 798–810.
3. Ball, R. P., and Marchbanks, S. S. Roentgen pelvimetry and fetal cephalometry; new technic. *Radiology*, 1935, *24*, 77–84.
4. Caldwell, W. E., and Moloy, H. C. Anatomical variations in female pelvis and their effect in labor with a suggested classification. *Am. J. Obst. & Gynec.*, 1933, *26*, 479–505.
5. Caldwell, W. E., Moloy, H. C., and D'Esopo, D. A. Further studies on pelvic architecture. *Am. J. Obst. & Gynec.*, 1934, *28*, 482–497.
6. Caldwell, W. E., Moloy, H. C., and D'Esopo, D. A. Further studies on mechanism of labor. *Am. J. Obst. & Gynec.*, 1935, *30*, 763–814.
7. Friedman, L. J., Michels, L. M., and Rossitto, A. F. Practical roentgen pelvimetry. *Surg., Gynec. & Obst.*, 1935, *61*, 735–742.
8. Haase. Quoted by Polak, J. O. Manual of Obstetrics. D. Appleton & Co., New York, 1914, p. 106.
9. Henrotay, J. L. Le radio-diagnostic obstétrical. *Gynec. et obstét.*, 1931, *24*, 265–298.
10. Jacobs, J. B. Roentgenography in obstetrics. *Radiology*, 1937, *28*, 406–426.
11. Johnson, C. R. Stereoroentgenometry; method for measuration by means of roentgen ray. *Am. J. Surg.*, 1930, *8*, 151–163.
12. Johnson, C. R. X-ray examination of obstetrical patient. *West J. Surg.*, 1936, *44*, 21–27.
13. Jungman, M. Zur Röntgendiagnose des intrauterinen Fruchttodes. *Zentralbl. f. Gynäk.*, 1928, *52*, 2788–2791.
14. Köhler, A. Röntgenology. William Wood & Co., New York, 1928, pp. 144, 160.
15. Mathieu, A. Value of hysterosalpingography in gynecologic diagnosis. *Radiology*, 1937, *28*, 427–435.
16. Matthews, H. B. Roentgen ray as an adjunct in obstetric diagnosis. *Am. J. Obst. & Gynec.*, 1930, *20*, 612–632.
17. Menees, T. O., and Holly, L. E. Ossification in extremities of new-born. Am. J. Roentgenol. & Rad. Therapy, 1932, *28*, 389–390.
18. Menees, T. O., Miller, J. D., and Holly, L. E. Amniography; preliminary report. Am. J. Roentgenol. & Rad. Therapy, 1930, *24*, 363–366.
19. Moloy, H. C. New method of roentgen pelvimetry; preliminary report. Am. J. Roentgenol. & Rad. Therapy, 1933, *30*, 111–114.

20. Peterson, R. Value of pneumoperitoneal roentgenography in obstetrics and gynecology. *J. Am. M. Ass.*, 1922, *78*, 397–400.
21. Portes, L., and Blanche. Le radio-diagnostic obstétrical. *Gynec. et obstét.*, 1924, *10*, 333–358.
22. Pryor, J. W. Differences in time of development of centers of ossification in male and female skeleton. *Anat. Rec.*, 1923, *25*, 257–268.
23. Scammon, R. E., and Calkins, L. A. Development and Growth of External Dimensions of Human Body in Fetal Period. University of Minnesota Press, Minneapolis, 1929.
24. Schnitker, M. A., Hodges, P. C., and Whitacre, F. E. Roentgenologic evidence of fetal death. Am. J. Roentgenol. & Rad. Therapy, 1932, *28*, 349–371.
25. Spalding, A. B. Pathognomonic sign of intrauterine death. *Surg., Gynec. & Obst.*, 1922, *34*, 754–757.
26. Tengbergen, J. Van E. Diagnosis of death of fetus. *Nederl. Tijdschr. v. Geneesk.*, 1926, *1*, 522–525. Abst. in *J. Am. M. Ass.*, 1926, *86*, 1592.
27. Thoms, H. X-ray pelvimetry; simplified technique. *Surg., Gynec. & Obst.*, 1927, *45*, 827–828.
28. Thoms, H. Determination of fetal maturity in utero. *Am. J. Obst. & Gynec.*, 1930, *20*, 807–811.
29. Thoms, H. Fetal cephalometry in utero. *J. Am. M. Ass.*, 1930, *95*, 21–24.
30. Thoms, H. Roentgen pelvimetry; description of grid method and a modification. *Radiology*, 1933, *21*, 125–130.
31. Ude, W. H., and Urner, J. A. Roentgenologic diagnosis of placenta previa. *Minnesota Med.*, 1935, *18*, 9–11.
32. Walton, H. J. Intrauterine roentgen cephalometry and pelvimetry. Am. J. Roentgenol. & Rad. Therapy, 1931, *25*, 758–760.
33. Walton, H. J. Roentgenological pelvimetry and intra-uterine cephalometry. *Surg., Gynec. & Obst.*, 1931, *53*, 536–568.
34. Walton, H. J. Roentgen pelvimetry and cephalometry. *South. M. J.*, 1932, *25*, 1060–1061.

Vol. 44, No. 4

SQUAMOUS CELL EPITHELIOMA OF THE CERVIX UTERI WITH BONE METASTASIS

REPORT OF TWO CASES

By ELMA BARANY, M.D., *and* ANGELO M. SALA, M.D.
*From the Pathology Laboratory, New York City Cancer Institute**
NEW YORK CITY

METASTASIS to bone from a primary lesion of the cervix uteri is still considered rare, perhaps because it is often neither expected nor looked for. It usually does not give any symptoms at the beginning, and a thorough roentgen examination of the skeletal system is seldom carried out in a case of epithelioma of the cervix.

Not so long ago it was generally believed that extensions of epithelioma of the cervix were as a rule confined to the pelvic cavity, involving the adnexa and pelvic nodes, and metastases to distant organs were hardly worth considering. Today, however, since the primary lesion is more often held in check or even entirely cured by the modern methods of treatment, widespread metastases occur with greater frequency, because the longer survival of the patient allows more time for their development. Lately more and more case reports of distant metastases have appeared in the literature, including involvement of bony structures.

In the German literature there are numerous cases reported by Philipp[14,15] and also by Traube[18] where a direct continuity from the primary neoplasm in the cervix or from its extension to the adnexa, or from one of the metastatic pelvic nodes could be traced to the lumbar vertebrae. In these cases the bone is attacked, either through its cortex by erosion, or by direct lymphatic extension. Philipp believes that about 15 per cent of the cervical lesions show such bone involvement and these are usually restricted to the pelvic bones or lumbar vertebrae but he mentions only one case with real distant metastasis, in which the left humerus was involved.

Norris[11] states that among his 43 cases of adenocarcinoma of the cervix, 9 had palpable metastases—but he does not specify the location.

Albers-Schönberg,[1] as long ago as 1893, reported 5 instances of skeletal metastasis in 564 cases of carcinoma of the cervix.

Moore,[10] in 1909, in discussing the roentgen appearances of the different types of metastatic lesions of bone, mentions only one case from carcinoma of the uterus.

MacCormac[8] in a statistical report from the Middlesex Hospital found only one cervical carcinoma with metastasis to the spine in 241 cases of carcinoma of the cervix.

Clairmont,[3] in 1909, published several cases of unusual metastasis, among which he describes one case of carcinoma of the cervix uteri in which there were metastases in the skin and also in the right fibula with a pathological fracture at the latter site.

Wertheimer[20] compared the metastatic spread in 54 irradiated and 50 non-irradiated cases of carcinoma of the cervix; he found only one instance of bone involvement in each group.

Joll[6] expresses the opinion that instances of bone metastases would be found much more frequently if the whole skeletal system were to be routinely examined. He describes in a case of carcinoma of the cervix a fracture of the right humerus, where the arm was removed under the impression that it was the seat of a primary tumor.

The only unusually high percentage is found in Ford's[5] paper of 1930, in which she studied the distant metastases in 24 cases of carcinoma of the cervix, and found 13 cases with lung and 14 cases with bone metastasis, making the incidence of the latter 59 per cent. She states that the

* Division of Cancer, Department of Hospitals, Dr. Ira I. Kaplan, Director.

radiating pain in carcinoma of the cervix usually believed to be due to nerve compression is often the result of metastatic involvement of the bone. In several of her cases no histological examination of the bone lesion was made and in numerous cases the reported involvement was located in the pelvis alone.

Faerber,[4] in discussing the cause of death in 150 cases of carcinoma of the uterus that came to autopsy, reports 22 cases, or 14 per cent, with bone involvement. These were located mainly in the vertebrae, and would appear to be direct extensions rather than true metastases.

Von Oettingen and Helfferich[12] believe that bone metastasis occurs in about 15 per cent of the cases of malignant tumors of the female genital tract. They describe one case of carcinoma of the cervix where a huge defect in the sacrum was found on roentgen examination, which proved to be carcinoma on histological examination. This involvement, however, also appears to be a direct extension rather than true metastasis.

Rosh[17] reports a single case of plexiform epithelioma of the cervix in a series of 233 cases, where a metastatic involvement was found in the left tibia three years after the primary tumor was healed by radium and roentgen treatment. A biopsy from the tibia yielded the same histologic picture as that of the primary neoplasm.

Warren,[19] while studying the distribution of distant metastases in 1,059 autopsies, in patients dead of malignant neoplastic disease, found 132 cervical carcinomas of which only 5 showed bone metastases, all of which were of the osteoclastic type. He asserts that there is a definite relation between the degree of malignancy and the total number of sites of metastasis; the higher the grade, the more unusual the metastatic involvement.

Kelly[7] presents the very unusual case of a Japanese woman, where biopsies from the breast and left humerus showed identical adenocarcinoma, which was traced back to a primary lesion in the cervix treated years previously in Tokio.

Reich,[16] discussing the question of metastases from uterine carcinoma, describes several unusual metastases, to lungs, heart, spleen and three to bone, mainly the vertebrae. He believes that bone metastasis always occurs through the blood stream.

Pearson,[13] in analyzing the cause of death in 57 cases of carcinoma of the cervix, found distant metastasis in 25 per cent, with 4 cases, or 7 per cent, showing involvement of bone.

Burke[2] reports 22 distant metastases in 53 cases of cervical carcinoma, among which 3 showed bone involvement.

Millar[9] found a very extensive destructive lesion involving the lower end of the right femur, upper end of the right tibia, fibula and right patella from a carcinoma of the cervix, in a white female, aged thirty-six.

In our institution, among 115 cases of squamous cell epithelioma of the cervix that came to autopsy, we found only 2 cases with definite metastatic involvement of bone, confirmed by histological examination.

Case 1 (Autopsy No. ccxvi-1936). Patient, a white female, aged forty-six, was admitted to the Cancer Hospital on September 9, 1933, complaining of irregular vaginal bleeding and discharge of seven months' duration. Menses were normal. Patient had three children, all living and well.

Vaginal examination revealed that the anterior lip of the cervix was destroyed, and the posterior lip transformed into a neoplastic mass. The adnexa was shortened, but not indurated. A clinical diagnosis of carcinoma of cervix was made, confirmed by biopsy, which showed a squamous cell epithelioma of the cervix, Grade 2–3.

Between September 11 and November 10, 1933, the patient received high voltage roentgen therapy to the pelvis through four portals, 1,000 r to each.

On September 15, 1933, two tandem and three cork colpostats were applied to the cervix and vagina totaling 7,526 mc-hr.

On October 4, 1933, the patient was transferred, considerably improved, to our ambulatory clinic.

On a re-examination on July 11, 1934, the cervical os could not be made out and only slight oozing was noted from one point of the vaginal dome. The patient was seen at short intervals and found to be in fairly good condition, without any recurrence at the primary site.

In January, 1935, she started to complain of pain in the left arm which she said dated back to a fall; roentgen examination of the shoulder and left humerus showed no abnormal changes at this time.

In October, 1935, the patient came to the clinic complaining of pain in the lower back and chest. There was no bleeding or discharge noted from the vagina, the cervix could not be found, and atresia of the upper vaginal wall closed off the cervical os. Rectal examination revealed some nodular induration of the right adnexa.

In October, 1935, the patient started another series of high voltage roentgen treatments which she did not complete, failing to keep her appointments.

Fig. 1 Case 1.

Fig. 2. Case 1.

Roentgenographic examination of chest on October 24, 1935, showed several irregular circular shadows in the left lung suggesting metastatic involvement.

On February 8, 1936, the patient was readmitted to our Hospital in a weak, cachectic condition with the chief complaints of cough, severe chest pain and low backache. On February 26, 1936, intravenous pyelography indicated anuria, on the right side. On March 6, 1936, re-examination of the chest showed increase in the metastatic involvement of left lung. The patient received high voltage roentgen therapy to the left chest between March 9 and April 4, 1936, a dosage of 875 r. On October 3, 1936, thoracocentesis of the left chest revealed 150 cc. of sanguineous fluid. Histological sections prepared from the sediment showed well defined islands of epithelioma.

Pain in the left shoulder increased in severity. Roentgen examination done on December 7,

Fig. 3. Case 1.

1936, showed a pathological fracture in the upper end of the left humerus (Fig. 1). From this time on patient declined rapidly and died on December 16, 1936.

At autopsy, the right lung showed discrete miliary, grayish, elevated depositions on the visceral pleura with a few similar areas in the parenchyma. On the left side, inseparable adhesions were found between mediastinal pleura and pericardium. The pleura over the lower lobe was tremendously thickened, measuring at one point 6 cm., and compressed the lung. The thickness of the diaphragmatic and mediastinal pleura was 2 cm. Just above the apex of the left ventricle a pea-sized grayish nodule was found on the visceral pericardium.

The liver showed only one neoplastic deposition—3 cm. in diameter—on the anterior surface of the right lobe just above the edge.

A few of the retroperitoneal nodes in the region of the pancreas were enlarged and neoplastic; also small groups of such nodes were found at the hilum of the left suprarenal gland, which however was not invaded.

The right ureter was enormously dilated—to the size of a loop of small gut; the right kidney was transformed into a thin walled sac, collapsing immediately when the ureter was severed.

The pelvic organs were removed in toto. Examination disclosed a complete atresia of the upper portion of the vagina, with a blind smooth surface covering the site of the cervical os. On opening the small uterus there was an escape of clear fluid, and at the site of the cervix there was found a dilatation 35 mm. in diameter, surrounded by uninfected neoplastic-looking tissue. On the right side this apparently neoplastic tissue had enveloped the ureter at its terminal portion and obstructed it.

A complete fracture of the surgical neck of the left humerus was found, where the bone marrow was replaced by neoplastic tissue.

Anatomical Diagnosis:

(1) Post-irradiation recurrent carcinoma of the cervix uteri with local extension.
(2) Metastatic carcinoma of retroperitoneal nodes, lung, liver, pleurae, pericardium

Fig. 4. Case 1.

and left humerus—with pathological fracture.

(3) Right hydroureter and hydronephrosis.

Histologic examination of the metastatic lesions in the different organs shows the same type of squamous cell epithelioma as found in the biopsy; in the recurrent lesion of the cervix, however (Fig. 2), there is a marked increase in the connective tissue stroma with some hyalinization. Even the metastatic lesion of the humerus (Fig. 3) retained its characteristics, showing solid islands of squamous cell epithelioma between the bony trabeculae, with extension into the surrounding soft tissues (Fig. 4).

Case II (Autopsy No. CCXXIII-1936). Patient, a white female, aged fifty-four, came to the Cancer Hospital on September 17, 1936, complaining of post-menopausal vaginal spotting which started six months ago with a severe hemorrhage. For three months she had also had dysuria, frequency, dull lower abdominal pain, shooting down to left leg. Patient was treated for the same symptoms at another city hospital in June and August, 1936, where she received 1,800 r through three portals to the pelvis, 2,400 mg-hr. radium to the vagina and 5,760 mg-hr. to the cervix.

On admission to our hospital she appeared to be markedly anemic and emaciated. Vaginal examination revealed a deep crater in the region of the cervix, nodular infiltration of the vaginal canal with induration of both adnexa.

Difficulty and pain on urination increased; intravenous pyelogram (November 24, 1936) showed marked hydronephrosis on right side with anuria on the left. On November 27 cystostomy was performed for drainage. On December 21, the patient complained of severe pain in her left knee, no deformity was found on examination, but roentgenograms showed destructive involvement of the left patella and upper part of the left tibia. On December 30, 1936, the patient had a severe hemorrage and died.

At autopsy several small, irregular, somewhat elevated, whitish depositions were found scattered throughout over both lower lobes of the lungs, but the parenchyma proper showed no metastases. Hilar nodes showed marked enlargement. All the retroperitoneal nodes—up to the diaphragm—were also markedly enlarged and neoplastic.

The left ureter was very much distended down to its origin where it was caught in the neoplastic extension from the cervix. While opening the left kidney a large amount of creamy pus escaped, the organ presented a far advanced pyelonephritis with marked destruction of the parenchyma. The right ureter was moderately distended and the right kidney showed moderate pyonephrosis. The pelvic organs were taken out in toto. The wall of the urinary bladder was thickened, and there was hemorrhagic congestion of the mucosa. The cervix was entirely destroyed and replaced by necrotic tumor tissue, which extended also to the vaginal wall and lower segment of the uterus. Tubes and ovaries could be identified, but the broad ligament was a mass of neoplastic tissue. All the pelvic nodes presented metastatic involvement.

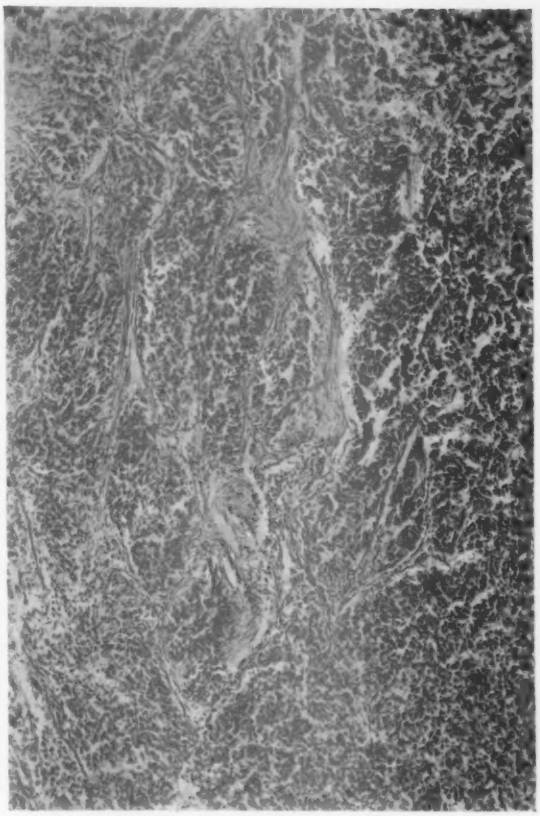


Fig. 5. Case II.

The upper portion of the left tibia in the region of the tuberosity showed an irregular elevation about 12 mm. in diameter. On cut section the bony structure in the region of the tuberosity and lateral condyle was replaced by neoplastic tissue, which apparently extended also to the soft parts in the region of the ligamentum patellae.

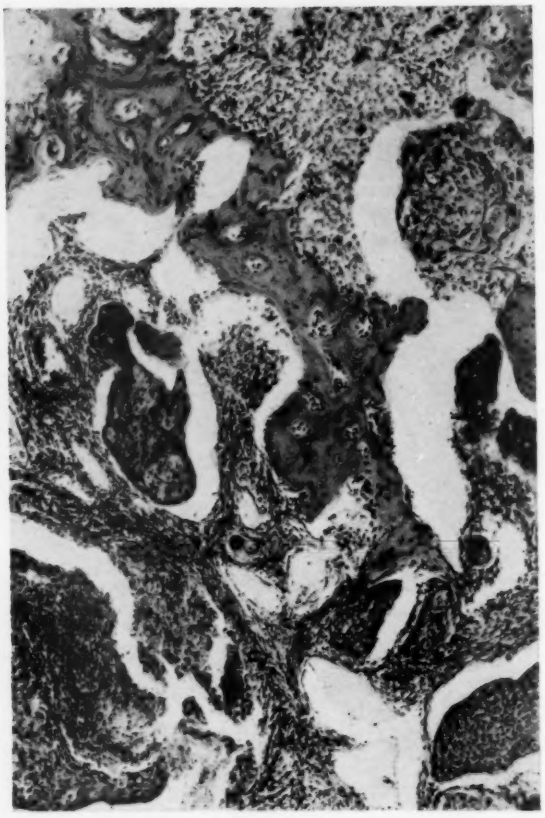


Fig. 6. Case II.

Anatomical Diagnosis:

(1) Carcinoma of the cervix uteri with extension to vaginal wall, lower segment of corpus and broad ligament.
(2) Metastatic carcinoma of pelvic, retroperitoneal and hilar lymph nodes, pleurae and left tibia.
(3) Left pyelonephritis and pyo-ureter.
(4) Right pyonephrosis.

Histologic examination of the cervix presents a rather cellular, infiltrating type of squamous cell epithelioma, with only scant intercellular stroma (Fig. 5). The same histologic picture is seen in all the metastatic lesions, including that in the tibia (Fig. 6).

Although bone is one of the most frequent sites of metastatic carcinoma—coming right after lung and liver—metastasis to distant bone from a primary carcinoma of the cervix, by true blood-borne embolus, still appears to be rather uncommon. It usually occurs only in those portions of the skeleton—humerus, tibia, femur, fibula—where the fatty marrow has already been changed into red marrow, due to the compensatory erythropoiesis, caused by marked secondary anemia.

This rarity is unusually striking on comparison with the bone depositions from the male genital organs, especially the prostate.

Direct invasion by continuity or lymphatic extension to the pelvic bones is more often described, but these should not be classed with the real distant metastases.

In several of the reported cases, moreover, no histological proof is offered of the metastasis to bone—the diagnosis resting only on a roentgenological basis.

No definite rules apply to dissemination of tumors, but still certain individual peculiarities deserve mention. In almost all the cases of carcinoma of the cervix with bone metastases, the primary lesion was entirely healed, or showed only little activity; in almost all the cases the disease was of long standing; usually there were already widespread metastatic depositions in the other organs, and the patient had been treated by one or more methods. Contrary to the usual diffuse, generalized involvement, characteristic of bony metastases, here we often meet with single lesions that are large, sometimes extending to surrounding tissues, not respecting the boundaries of the joint as metastatic bone lesions usually do.

SUMMARY AND CONCLUSIONS

1. Two cases of squamous cell epithelioma of the cervix uteri with true bone metastasis are described, with autopsy findings.

2. Some of the literature is briefly discussed.

3. True blood-borne metastases from primary carcinoma of cervix uteri are rare.

4. Bone metastases from carcinoma of the cervix uteri show some special peculiarities in that they tend to be single lesions of large size.

5. Invasions by contiguity and direct extensions should not be included among true blood-borne metastases.

REFERENCES

1. Albers-Schönberg, H. Beitrage zum Statistik des Carcinoma Uteri. Jahrb. d. Hamb. Staatskrankenanst., 1893–1894.
2. Burke, E. M. Metastases in squamous-cell carcinomas. *Am. J. Cancer*, 1937, *30*, 493–503.
3. Clairmont, P. Einige Fälle von seltene Geschwulstmetastasen. *Arch. f. klin. Chir.*, 1909, *89*, 513–541.
4. Faerber, H. Woran sterben die nicht operierten bzw. rezidiv gewordenen Uteruskarzinomkranken? *Ztschr. f. Geburtsh. u. Gynäk.*, 1931, *99*, 213–226.
5. Ford, F. A. Distant metastasis in carcinoma of cervix of the uterus. *Minnesota Med.*, 1930, *13*, 489–494.
6. Joll, C. A. Metastatic tumours of bone. *Brit. J. Surg.*, 1923, *11*, 38–72.
7. Kelly, J. A. Unusual metastases of carcinoma of the uterus. *Surg. Clin. North America*, 1933, *13*, 468–471.
8. MacCormac, H. Malignant diseases of the cervix uteri. *Arch. Middlesex Hosp.*, 1909, *15*, 20–28.
9. Millar, W. M. Carcinoma of cervix with patellar metastases. *Am. J. Cancer*, 1937, *29*, 122–124.
10. Moore, A. B. Roentgenologic study of metastatic malignancy of bones. Am. J. Roentgenol., 1919, *6*, 589–593.
11. Norris, C. C. Adenocarcinoma of cervix. *Am. J. Cancer*, 1936, *27*, 653–675.
12. von Oettingen, K., and Helfferich, M. Beitrag zur Frage der Knochenerkrankungen nach Genitalkarzinom. *Zentralbl. f. Gynäk.*, 1932, *56*, 1574–1577.
13. Pearson, B. Factors in cause of death in carcinoma of cervix. *Am. J. Cancer*, 1936, *28*, 31–39.
14. Philipp, E. Röntgenologische Darstellung von Knochenerkrankungen beim Uteruskarzinom und ihr Verlauf. *Zentralbl. f. Gynäk.*, 1932, *56*, 45–58.
15. Philipp, E. Uteruskarzinom und Knochensystem. *Deutsche med. Wchnschr.*, 1934, *60*, 710–713.
16. Reich, W. Zur Frage der Metastasierung des Uteruskrebses. *Ztschr. f. Geburtsh. u. Gynäk.*, 1933, *104*, 209–227.
17. Rosh, R. Carcinoma of cervix with bone metastasis. *Radiology*, 1932, *18*, 638–640.
18. Traube, K. Zur Frage der Knochenmetastasen nach Collumkarzinom. *Zentralbl. f. Gynäk.*, 1933, *57*, 2909–2914.
19. Warren, S. Studies on tumor metastasis; distribution of metastases in carcinoma of cervix uteri. *Surg., Gynec. & Obst.*, 1933, *56*, 742–745.
20. Wertheimer, S. Die Metastasierung bestrahlter und nicht bestrahlter Kollumkarzinome. *Strahlentherapie* 1921, *12*, 90–96.

LATE RESULTS IN SUPERVOLTAGE ROENTGEN THERAPY

COMPARATIVE STATISTICAL ANALYSIS IN SELECTED GROUPS*

By T. LEUCUTIA, M.D.
Department of Radiology, Harper Hospital
DETROIT, MICHIGAN

PREVIOUS publications seemed to indicate, on the basis of physical measurements and clinical experience, that supervoltage roentgen therapy in certain groups of cancer has a decided advantage over deep roentgen therapy because of a more homogeneous distribution and a greater efficacity of the rays. The immediate results many times appeared superior and were secured with comparatively less damage to the skin and normal structures. The late results, however, were soon found to be a function of the good immediate effect and the relatively low malignancy index of the irradiated neoplasm. Only those cases could be expected to survive for a greater length of time in which the malignant process remained longer of local character.

In the present paper the late results are analyzed. To gain a better evaluation, (I) the cases treated by supervoltage roentgen therapy in 1933–1934 at Harper Hospital are tabulated as a whole and the three and five year survival rates studied; then (II) certain groups—ten altogether—in which the method proved of more definite value were selected and their survival rates compared with those obtained by deep roentgen therapy during the same period or previously, as far back as 1922. The year 1935, in which 174 cases were treated by supervoltage roentgen therapy, was also added, in order to have a larger number of supervoltage cases for the three year comparison. It may be mentioned here that in the follow-up, only the cases known to be, or to have been, alive at the particular period analyzed are considered as survivals for that period. All untraced cases, which amount to about 2 per cent of the total, and all persons found to be dead were presumed to have died from cancer, even though at the postmortem examination no trace of the malignant process might have been present. In this manner, the results shown here represent the lowest figures possible, and their improvement with location of some of the untraced cases may be expected, especially since experience proves that most of the lost cases eventually reappear, free of cancer.

I. TABULAR SUMMATION OF CASES TREATED BY SUPERVOLTAGE ROENTGEN THERAPY DURING 1933–1934

The number of cases amounts to 312. They are divided into 2 series: (1) those in which previous deep roentgen therapy had failed, although the dose was pushed to the uppermost limit compatible with that type of irradiation and (2) those in which supervoltage roentgen therapy was used from the beginning. The voltage range in the deep roentgen therapy represented 200 kv. equivalent (1 mm. Cu) whereas in the supervoltage roentgen therapy, it varied between 500 and 600 kv. equivalent (7 mm. Cu).

(1) The first series includes 93 cases. The three and five year survivals are shown in Table 1.

As is seen in Table 1, of 93 cases which proved failures of deep roentgen therapy and which secondarily were treated with supervoltage roentgen therapy, only 8 per cent survived the three year and 4.5 per cent the five year period. It is therefore evident that if deep roentgen therapy was unsuccessful in bringing about the desired effect in a particular case of cancer, very little or practically nothing can be expected

* Read at the Fortieth Annual Meeting, American Roentgen Ray Society, Chicago, Ill., Sept. 19–22, 1939.

from the subsequent irradiation with more penetrating roentgen rays.

(2) The second series embraces 219 cases. Their three and five year results are shown in Table II.

A general survey of all cases in this series shows that the three year survival amounted to 34 per cent and the five year survival to nearly 30 per cent. A more detailed analysis of the individual groups, however, immediately impresses the observer with the fact that in some types of cancer, the favorable results appear quite high, whereas in others they are low or non-existent. This, then, incited investigation in another direction. It was thought that perhaps more accurate information could be derived by making the comparison with the results of deep roentgen therapy as the basis of study.

Table I

CASES SECONDARILY TREATED WITH SUPERVOLTAGE ROENTGEN THERAPY AFTER DEEP ROENTGEN THERAPY FAILED (1933–1934)

Type of Malignant Growth	Year	Total	Alive 3 yr.	Alive 5 yr.
Breast cancer	1933	6	—	—
	1934	2	1	—
Oral cancer	1933	4	1	1
	1934	3	—	—
Gastrointestinal cancer	1933	5	—	—
	1934	6	—	—
Genitourinary cancer	1933	—	—	—
	1934	5	—	—
Uterine cancer	1933	18	1	1
	1934	17	2	1
Ovarian cancer	1933	7	1	1
	1934	1	—	—
Sarcoma	1933	4	—	—
	1934	6	—	—
Various malignant growths	1933	2	—	—
	1934	7	1	1
Total		93	7	5

Table II

CASES PRIMARILY TREATED WITH SUPERVOLTAGE ROENTGEN THERAPY (1933–1934)

Type of Malignant Growth	Year	Total	Alive 3 yr.	Alive 5 yr.
Skin cancer (bulky)	1933	1	—	—
	1934	5	3	2
Breast cancer (bulky)	1933	7	2	2
	1934	7	—	—
Oral cancer with metastasis to glands of neck	1933	12	2	2
	1934	14	6	6
Cancer of thyroid	1933	3	2	1
	1934	2	1	1
Cancer of larynx	1933	3	1	—
	1934	10	2	2
Gastrointestinal cancer	1933	5	—	—
	1934	15	—	—
Cancer of rectum	1933	4	2	2
	1934	4	2	1
Genitourinary cancer	1933	3	—	—
	1934	4	—	—
Cancer of bladder and prostate	1933	3	1	1
	1934	11	3	2
Uterine cancer	1933	24	14	12
	1934	34	22	19
Ovarian cancer	1933	5	—	—
	1934	6	—	—
Cancer of bronchus	1933	8	1	1
	1934	5	2	2
Sarcoma	1933	7	1	1
	1934	17	7	6
Total		219	74	63

II. COMPARATIVE STUDY OF SUPERVOLTAGE ROENTGEN THERAPY RESULTS WITH THOSE OF DEEP ROENTGEN THERAPY

In pursuing such a study two procedures are followed. On the one hand, the supervoltage roentgen therapy results are analyzed in the light of former results obtained with deep roentgen therapy by making a

postliminary comparison and, on the other, they are compared whenever possible with the results gained in the cases treated during the same period with deep roentgen therapy. Fortunately, in several of the groups, there is a sufficient number of cases

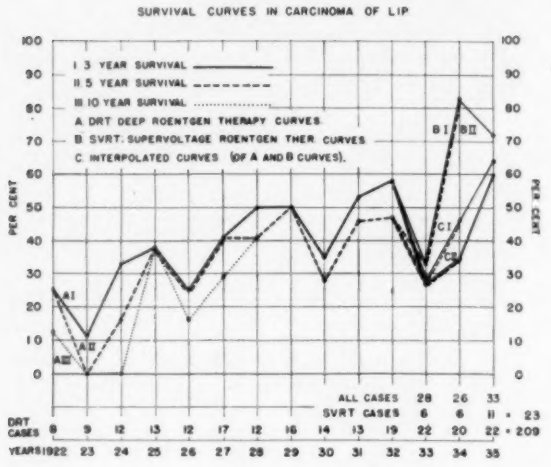

SURVIVAL CURVES IN CARCINOMA OF LIP
I. 3 YEAR SURVIVAL
II. 5 YEAR SURVIVAL
III. 10 YEAR SURVIVAL
A. DRT DEEP ROENTGEN THERAPY CURVES
B. SVRT. SUPERVOLTAGE ROENTGEN THER. CURVES
C. INTERPOLATED CURVES (OF A AND B CURVES).
PER CENT
ALL CASES 28 26 33
SVRT CASES 6 6 11 • 23
DRT CASES 8 9 12 13 12 17 12 16 14 13 19 22 20 22 • 209
YEARS 1922 23 24 25 26 27 28 29 30 31 32 33 34 35

Fig. 1

that postliminary and contemporaneous comparisons are possible. Survival curves for three, five and ten years are plotted for the deep roentgen therapy series as far back as 1922. Beginning with 1933, curves for the supervoltage roentgen therapy series are added and to make the influence of this type of irradiation on the total results more evident, curves for all cases are interpolated.

In the ten groups chosen, a total of 231 supervoltage roentgen therapy cases treated between 1933 and 1935 are compared with 1,354 cases irradiated with deep roentgen rays between 1922 and 1935.

(1) *Carcinoma of the Lower Lip.* It appeared from early investigation that the use of supervoltage roentgen therapy might have some value in cancer about the face or neck with extension to the regional lymph nodes because of the great difficulty in irradiating such regions homogeneously with the 200 kv. therapy. A good example in this respect is the metastatic carcinoma to the submental, submaxillary or cervical lymph nodes from a primary source in the lip where, as is now generally acknowledged, nothing can be expected from deep roentgen therapy and where the final results remain invariably bad.

The first similar cases treated by supervoltage roentgen therapy in 1933 seemed to point to a more favorable outlook. Even large metastatic tumors often regressed readily and in certain instances a complete eradication of the malignant process was obtained. Since then, it has been found that in 30 per cent of such cases a three year and in 20 per cent a five year survival may be expected.

This improved irradiation response induced us in 1934 to treat routinely with supervoltage roentgen therapy all cancers of the lip, face, oral cavity, nasopharynx, etc., in which there was presence or even suspicion of metastases to the regional lymph nodes of the neck. The influence of such procedure on the survival curves in the case of cancer of the lip is shown in Figure 1.

As may be noted, there is an increase of the three year survivals to an average of 65 per cent and of the five year survivals to an average of 58 per cent in the supervoltage therapy cases, although they represented clinically more advanced and thus less favorable stages. This increase effected a rise also in the total results as evidenced by the interpolated curves. The steady improvement of the deep roentgen therapy curves prior to the use of supervoltage roentgen therapy must be attributed to the fact that whereas in the beginning only the very advanced cases were referred for irradiation, the early cases being operated upon, with time radiation therapy gradually replaced surgery. At present, nearly all cases, whether in an early or late stage, are being treated by irradiation methods solely.

(2) *Carcinoma of the Tongue.* A still better illustration of the good action of supervoltage roentgen therapy on the metastatic process to the high lymph nodes of the neck is obtained in carcinoma of the tongue. In this group, in our series not less than 88 per cent of the cases already possessed

extensive metastases to the regional lymph nodes when referred to radiation therapy, a fact which incidentally explains the exceedingly poor final results prior to 1933 (Fig. 2).

The introduction of supervoltage roentgen therapy led to decided improvement, the average three year survival rising to more than 40 per cent.

(3) *Carcinoma of the Larynx.* Two other types of cancer were chosen in connection with the irradiation around the neck which, from the point of view of irradiation prognosis, constitute widely diverging groups:

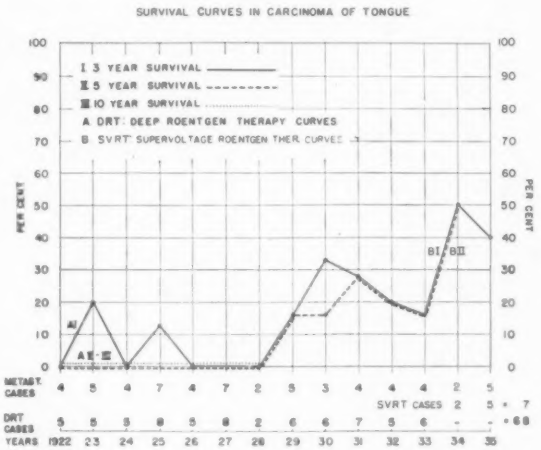


FIG. 2

carcinoma of the larynx and carcinoma of the thyroid.

In carcinoma of the larynx the late results obtained with deep roentgen therapy over a long period of years were practically nil. The substitution of supervoltage roentgen therapy led to an average survival of 26 per cent for the three year and 15 per cent for the five year period, thus apparently producing some improvement (Fig. 3). It must be conceded, however, that even so these results do not measure up favorably with the figures of other investigators obtained with the 200 kv. therapy.

(4) *Carcinoma of the Thyroid.* On the other hand, in carcinoma of the thyroid, the good results obtained by deep roentgen therapy continued to remain about the same also with the supervoltage roentgen

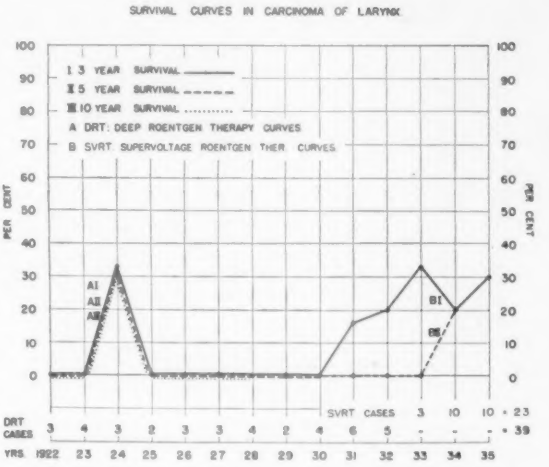


FIG. 3

therapy (Fig. 4). The respective average percentages for the three year survivals were 53 and 55 and for the five year survivals 41 and 40.

It thus appears that if the cancer is localized to the structures of the neck proper, the irradiation with 200 kv. is efficacious enough so that very little, if any, advantage may be derived from irradiation with more penetrating roentgen rays.

(5) *Carcinoma of Cervix Uteri.* Perhaps the best group of cases for testing the value of supervoltage roentgen therapy is represented by the gynecologic cancers for they meet all the requirements for betterment of the homogeneity of the irradiation

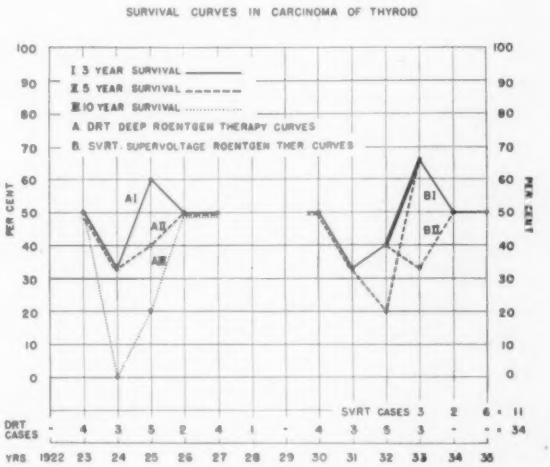


FIG. 4

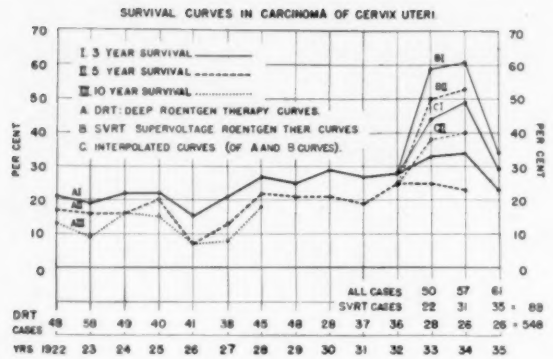

SURVIVAL CURVES IN CARCINOMA OF CERVIX UTERI
I 3 YEAR SURVIVAL
II 5 YEAR SURVIVAL
III 10 YEAR SURVIVAL
A DRT: DEEP ROENTGEN THERAPY CURVES.
B SVRT SUPERVOLTAGE ROENTGEN THER CURVES
C INTERPOLATED CURVES (OF A AND B CURVES).
PER CENT
PER CENT
ALL CASES 50 57 61
SVRT CASES 22 31 35 + 88
DRT CASES 49 58 49 40 41 38 45 48 28 37 36 28 26 26 + 548
YRS 1922 23 24 25 26 27 28 29 30 31 32 33 34 35

Fig. 5

and remain localized for a comparatively long duration. To this may be added the rather large number of cases arriving under treatment.

In carcinoma of the cervix uteri, the average deep roentgen therapy results prior to 1933 amounted to 25 per cent for the three year and 19 per cent for the five year survival. From 1933 to 1935 about half of the cases were treated with supervoltage roentgen therapy and the other half continued to receive irradiation with the 200 kv. rays (Fig. 5).

It may be noted that whereas in the deep roentgen therapy cases the three and five year figures remained practically unchanged, the results obtained with supervoltage roentgen therapy increased in some years to as high as 60 per cent for the three year and 50 per cent for the five year survival.

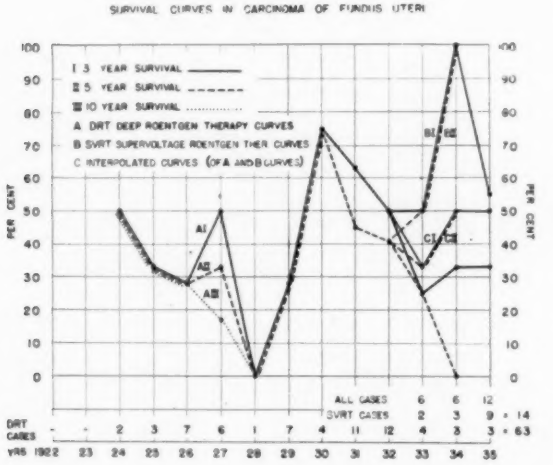

SURVIVAL CURVES IN CARCINOMA OF FUNDUS UTERI
I 3 YEAR SURVIVAL
II 5 YEAR SURVIVAL
III 10 YEAR SURVIVAL
A DRT DEEP ROENTGEN THERAPY CURVES
B SVRT SUPERVOLTAGE ROENTGEN THER CURVES
C INTERPOLATED CURVES (OF A AND B CURVES)
PER CENT
PER CENT
ALL CASES 6 6 12
SVRT CASES 2 3 9 + 14
DRT CASES - - 2 3 7 6 1 7 4 11 12 4 3 3 + 63
YRS 1922 23 24 25 26 27 28 29 30 31 32 33 34 35

Fig. 6

In 1935, the figures are lower, but the relative difference between the two forms of radiation is maintained. Thus in this type of cancer both the postliminary and contemporaneous comparison of the cases supports the apparent superiority of supervoltage roentgen therapy over deep roentgen therapy.

(6) *Carcinoma of the Fundus Uteri.* The same may be said, with some reservation, of carcinoma of the body of the uterus (Fig. 6). Here, through the supplanting of supervoltage roentgen therapy the three year

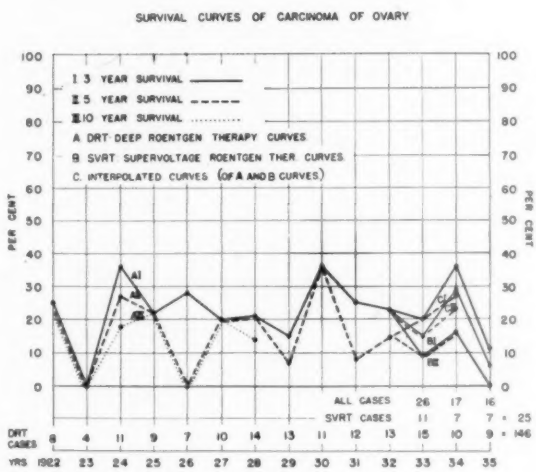

SURVIVAL CURVES OF CARCINOMA OF OVARY
I 3 YEAR SURVIVAL
II 5 YEAR SURVIVAL
III 10 YEAR SURVIVAL
A DRT DEEP ROENTGEN THERAPY CURVES
B SVRT SUPERVOLTAGE ROENTGEN THER CURVES
C INTERPOLATED CURVES (OF A AND B CURVES)
PER CENT
PER CENT
ALL CASES 26 17 16
SVRT CASES 11 7 7 + 25
DRT CASES 8 4 11 9 7 10 14 13 11 12 13 15 10 9 + 146
YRS 1922 23 24 25 26 27 28 29 30 31 32 33 34 35

Fig. 7

results have been increased from an average of 43 per cent to an average of 64 per cent and the five year results from an average of 37 per cent to an average of 60 per cent. The interpolated curves of all cases between 1933 and 1935 are, however, because of the rather poor results in the deep roentgen therapy series, somewhat lower than the former curves obtained with the 200 kv. therapy just prior to the institution of supervoltage roentgen therapy.

(7) *Carcinoma of Ovary.* Surprisingly, supervoltage roentgen therapy has failed to improve the results in carcinoma of the ovary, despite the fact that this type of cancer metastasizes to distant parts of the body quite late and the technical conditions for uniform irradiation are not unsatisfactory. Whereas in the deep roentgen

therapy series, the three and five year survivals amounted to 24 and 20 per cent respectively, in the supervoltage roentgen therapy they barely exceeded 10 per cent (Fig. 7). No satisfactory explanation can be given for this paradoxical behavior, for at least an equal response might have been expected. For the time being it is assumed that with a larger number of cases the situation may change and that, therefore, the unfavorable balance constitutes a purely incidental occurrence.

(8) *Carcinoma of Rectum.* It was thought

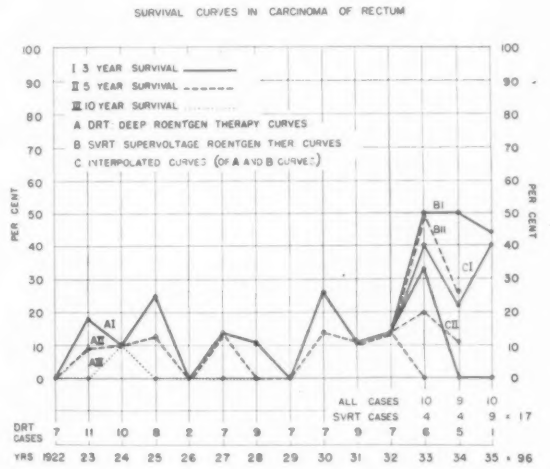

SURVIVAL CURVES IN CARCINOMA OF RECTUM
I 3 YEAR SURVIVAL
II 5 YEAR SURVIVAL
III 10 YEAR SURVIVAL
A DRT: DEEP ROENTGEN THERAPY CURVES
B SVRT SUPERVOLTAGE ROENTGEN THER CURVES
C INTERPOLATED CURVES (OF A AND B CURVES)
PER CENT
ALL CASES
SVRT CASES
DRT CASES
YRS 1922

Fig. 8

advisable to analyze also other types of pelvic cancers in which irradiation criteria are similar to those of the gynecologic cancers, but which pathologically represent different entities. Carcinoma of the rectum appeared, in this respect, a good selection. Indeed, it was found both by postliminary and contemporaneous comparison that the good results have been definitely increased (Fig. 8). In the deep roentgen therepy series 14 per cent of the cases reached the three year and only 7 per cent the five year period, but with the substitution of supervoltage roentgen therapy, 46 per cent of the cases survived three years and nearly 40 per cent five years.

(9) *Carcinoma of the Bladder.* In the beginning, some like improvement was discernible in carcinoma of the bladder, the

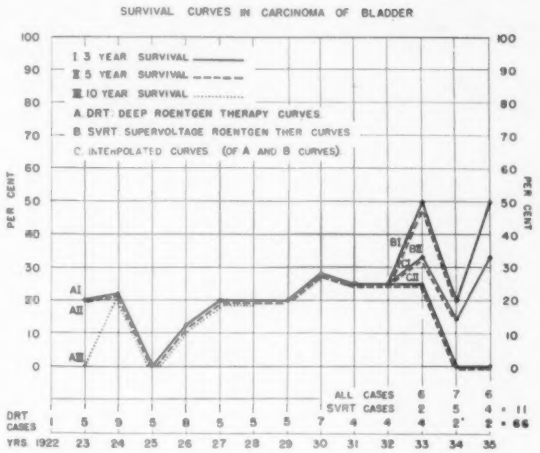

SURVIVAL CURVES IN CARCINOMA OF BLADDER
I 3 YEAR SURVIVAL
II 5 YEAR SURVIVAL
III 10 YEAR SURVIVAL
A DRT: DEEP ROENTGEN THERAPY CURVES
B SVRT SUPERVOLTAGE ROENTGEN THER CURVES
C INTERPOLATED CURVES (OF A AND B CURVES)
PER CENT
ALL CASES
SVRT CASES
DRT CASES
YRS 1922

Fig. 9

three year survivals rising from 21 per cent to 36 per cent (Fig. 9), but soon it was found that the local eradication of the cancer not infrequently was followed by the appearance of distant metastases. Finally, the five year results amounted to 29 per cent or less as compared to 20 per cent for the deep roentgen therapy group.

(10) *Carcinoma of the Prostate.* A slight benefit from supervoltage roentgen therapy was observed in cancer of the prostate (Fig. 10). In this group, 55 per cent of the patients presented themselves for treatment with evidence of metastases. Since palliation is all that could be expected in such instances, deep roentgen therapy was used, as a rule, whereas supervoltage roent-

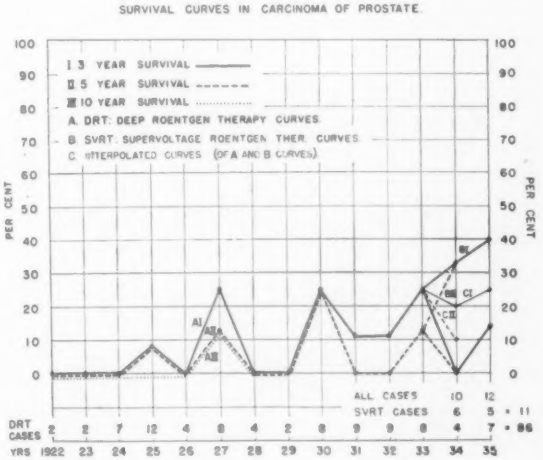

SURVIVAL CURVES IN CARCINOMA OF PROSTATE
I 3 YEAR SURVIVAL
II 5 YEAR SURVIVAL
III 10 YEAR SURVIVAL
A DRT: DEEP ROENTGEN THERAPY CURVES
B SVRT SUPERVOLTAGE ROENTGEN THER CURVES
C INTERPOLATED CURVES (OF A AND B CURVES)
PER CENT
ALL CASES
SVRT CASES
DRT CASES
YRS 1922

Fig. 10

gen therapy was reserved for the cases without apparent distant extension of the carcinoma. In this manner, the supervoltage roentgen therapy series comprises a more favorable group of cases and therefore neither the postliminary nor still less the contemporaneous comparison offers a true picture of the situation. Yet it seems that in the localized forms the 25 per cent three year and the 14 per cent five year survival rate constitutes some progress.

CONCLUSIONS

It is the purpose of the present paper to furnish statistical proof as to the superiority, if any, of supervoltage roentgen therapy with 500–600 kv. equivalent (7 mm. Cu) over that of deep roentgen therapy with 200 kv. equivalent (1 mm. Cu). An analysis of all cases treated in 1933–1934 indicates a three year survival of 34 per cent and a five year survival of nearly 30 per cent.

To gain a better insight into the meaning of these figures, ten groups of cancer were carefully selected and the results from both types of irradiation were studied by postliminary as well as contemporaneous comparison. Since an evaluation of the tout ensemble is the only aim, no particular attention is paid to the accessory methods of treatment in the case, such as association with surgery, radium application, lead therapy, etc., or to finer details of technical procedure. It is presumed, especially in the contemporaneous cases, that except for the variation in the quality of the roentgen rays used, everything else remained more or less the same. Furthermore, no cases were eliminated under any pretext, whether the treatment was carried out to a successful conclusion or remained incomplete, whether the cancer represented an early stage or was already so hopeless that a minimum measure of palliation could be expected at the best. In this manner, all results refer to the total number of cases within that particular group, as they presented themselves for medical care year after year.

It is evident from this study that supervoltage roentgen therapy in certain types of cancer is of some benefit. The number of cases may as yet be too small to permit an absolutely rigid conclusion, and some dwindling of the high figures may be expected with the accumulation of a larger series; nevertheless, it becomes increasingly apparent, as time goes on, that some progress toward betterment of the late results is being made in well selected groups.

DISCUSSION

Dr. David Steel, Cleveland, Ohio. Many who have heard this paper, and many who will read it later, will undoubtedly feel that Dr. Leucutia is a little over-enthusiastic about his results with supervoltage therapy. From my experience of nearly four years, using physical factors quite comparable, I feel that he has been quite conservative. From the accumulated experience, it seems safe to say that external radiation of the supervoltage type is sufficient alone to sterilize a high percentage of advanced cancers of the uterine cervix. Many such cases have been salvaged when radium could not have been used because of the presence of one or more of the well-known contraindications. Certainly deep therapy alone in the past has offered little as far as being a sole method for the successful treatment of an advanced cancer of the cervix, that is, deep therapy by itself. If deep therapy could not sterilize the primary lesion, it would have little effect on the pelvic extensions. In this respect it would seem that supervoltage therapy is a great improvement, because if supervoltage therapy will control the primary, it is certainly logical to believe that it has a better chance of controlling the extensions than does deep therapy. I feel that the same logic can be applied to the other sites mentioned by Dr. Leucutia. My experience with ovarian tumors is more encouraging than that mentioned by Dr. Leucutia, and I dare say his thought that his results will improve in this group is well founded.

There is another point in the use of supervoltage therapy which I think deserves to be brought out. We all realize that certain tumors, for instance those in the gastrointestinal tract, have proved quite resistant to deep therapy. They are also quite resistant to supervoltage therapy, and for all practical purposes they still

remain in the field of palliation. In reporting our results, it is quite natural to tabulate our three and five year survivals and to compare the figures with those of former years. Such tables, however, fail completely to show the results in one of the greatest fields of medicine, namely, palliation. Palliation is the primary goal of many of the endeavors in other branches of medicine and surgery; yet when it comes to methods in irradiation, it is too often forgotten and seldom mentioned. Many of our finest results in radiation therapy are in the field of pure palliation where the thought of cure could not even be hoped for. Why should we not feel about palliation in cancer the same as physicians in general feel about palliation in heart disease, chronic nephritis, hypertension, diabetes, and so on? In spite of the fact, then, that palliation is all that is left in many of the cases coming to us, we are still practicing excellent medicine. By improving our palliation, it might well be that we will approach nearer our ideal goal of cure. Such is the case, I feel, in supervoltage radiation. Palliation is far better in many of the tumors than it was with deep therapy, and this degree of palliation is reached with far less discomfort to the patient than a lesser degree of palliation with deep therapy.

Supervoltage therapy has undoubtedly come to stay. It is a great step forward not only in the direction of cure, but in the field of palliation as well.

ROENTGEN THERAPY FOR INFLAMMATORY CONDITIONS

FURTHER CONSIDERATIONS*

By ARTHUR U. DESJARDINS, M.D.
Section on Therapeutic Radiology, The Mayo Clinic
ROCHESTER, MINNESOTA

AT A COMPARATIVELY recent examination of the American Board of Radiology, at which I had been selected to act as an examiner, I asked one candidate how he would treat with roentgen rays a case of carbuncle, one of erysipelas, and one of tuberculosis of the wrist with involvement of both tendons and bones. His answers showed that he knew practically nothing about radiotherapy for inflammatory conditions. This particular candidate had received an exceptionally sound training in the treatment of malignant tumors with roentgen rays or radium. Apparently, he had been so preoccupied with the treatment of neoplasms, probably in an institution in which inflammatory lesions were seldom encountered, that he was hardly aware of the therapeutic value of irradiation in many forms of acute and chronic inflammation. It was apparent, also, that in perusing journals devoted to radiology, his attention had been confined to articles dealing with the treatment of tumors.

When I propounded similar questions to another candidate at the same examination, I received the rather startling answer that he would treat them all with three erythema doses. Here was a physician seeking recognition as a specialist in radiology, who obviously had not read a journal of radiology for ten or more years. One would think that, before presenting himself before a national board for examination in a branch of medicine in which the candidate was seeking to be recognized as a specialist, he would have taken the trouble to inform himself about the major developments in his particular branch.

There is no denying the fact that the application of roentgen rays and, to a limited extent, of radium to the treatment of inflammatory lesions is increasing steadily and will probably continue to increase for some time. It may not be very long, in fact, before the treatment of inflammations becomes as important a phase of radiotherapy as the treatment of malignant processes. In some institutions this status has almost been reached already. Unfortunately, but perhaps naturally, it is still too often true that this method of treatment is not considered, or its possible efficacy is not remembered, by medical or surgical clinicians until every other method has been tried with little or no success, or until, every other measure having failed, it is almost time to bring down the black curtain. Too often, during the early stage of acute inflammations known to be amenable to roentgen irradiation, the treatment is withheld until the inflammation has progressed beyond hope or until the best results of irradiation can no longer be expected. As more internists and surgeons become acquainted with and convinced of the value of roentgen therapy, this situation will no doubt be corrected. They will gradually learn that a suitable dose of roentgen rays given in time may save some lives and that, in acute inflammatory processes, a small or moderate dose given early will often make any other treatment unnecessary.

When a therapeutic method rests on a solid basis, no amount of opposition can prevent it from making its way to general acceptance until some better method is discovered. A corollary appears to be that, when a method becomes widely adopted, its fundamental basis is probably sound,

* Read at the Fortieth Annual Meeting, American Roentgen Ray Society, Chicago, Ill., Sept. 19–22, 1939.

even though its scientific background and the detailed principles which govern its action may not be understood at the time. This might well be regarded as a phase of a general law. Circumstances, of course, may greatly influence this process of recognition and acceptance.

In this country, many radiologists have been slow to realize the increasing number of reports from more or less reliable sources which have emanated from several European countries, especially since the war of 1914–1918. Some of these reports, notably those of Heidenhain and Fried,[8,9] included a large number of cases of different kinds of inflammatory conditions, in about 75 per cent of which excellent results were obtained.

To mention only one example out of many, the work of Thielemann, of Cochard, and of Meldolesi and Sabbadini,[17,30] on roentgen therapy for trachoma, especially in the early stages before the granulations have been replaced by connective tissue, has not been duplicated in the United States, probably because of an unfounded fear of deleterious effects on the eye on the part of ophthalmologists and radiologists. Yet it is now well known that the eyes of adults are not unduly sensitive to roentgen rays. The eye can readily tolerate the range of doses best suited for the treatment of inflammations, but it will take some time to overcome this perfectly natural fear on the part of those who are not familiar with the subject. In the meantime, many persons afflicted with trachoma will helplessly be allowed to lose their vision, in spite of the fact that a good proportion of them might perhaps be saved from such a dire consequence.

Another reason why many internists and surgeons hesitate to try roentgen therapy in acute inflammations is that they have in mind the systemic reaction which so frequently accompanies and follows the treatment of malignant tumors, and the unfortunate changes in the skin which sometimes arise weeks, months or years after the treatment of such lesions. It is difficult at first to make them realize that the treatment of acute inflammations is different in that the range of doses employed and the number of fields to be irradiated in most cases are so much smaller that the question of systemic (gastrointestinal) reaction or of deleterious changes in the skin practically disappears.

Anyone who thoroughly scans the extensive literature bearing on the treatment of acute and chronic inflammations with roentgen rays or radium cannot fail to be impressed by its volume and by the large number of different conditions in which the method has been found to yield excellent results. Many of the reports, it is true, are based on small groups of cases, and in others the diagnosis does not appear to have been firmly established. If all these are cast aside, there remains a considerable number of reports by experienced workers and careful observers which cannot be dismissed so lightly. But even among those which one might be tempted to disregard because they are based on a small number of cases, some might well be scrutinized with attention.

A good example is the report of Stephan (1920) of a few cases of anuria in which the anuria was promptly relieved after a small dose of roentgen rays. Stephan reported these cases as instances of cellular stimulation by roentgen rays. His cases, of course, did not prove anything of the kind. In 1923 Pordes[19,20] furnished a probably sound explanation of the favorable effect of the rays in the cases cited.

When anuria complicates nephritis (acute nephritis or an acute exacerbation of an old nephritis), the anuria is due to the rapid and marked swelling of the renal epithelium, the accumulation of exudate and serum in the glomeruli, tubules, and interstitial spaces, and the infiltration of the renal parenchyma by large numbers of leukocytes, chiefly polymorphonuclears and lymphocytes. The internal and external swelling of the kidneys within their capsule becomes so great that urine can no longer flow through the tubules into the

pelvis. According to Pordes, a small dose of roentgen rays, if given at the proper time, destroys a proportion of the infiltrating polymorphonuclear leukocytes and lymphocytes, the tubules are relieved from pressure, the anuria shortly disappears, and the cellular congestion in the renal parenchyma rapidly diminishes. However, such an explanation, even though it harmonizes with pathology and with radiology, is too simple for minds that like complicated explanations, even if these cannot be reconciled either with pathology or with radiology. What probably happens in lobar pneumonia, when resolution is delayed and when a small dose of roentgen rays is given to the affected lung before organization of the pneumonic exudate has progressed too far, is such a perfect analogy that one cannot help being struck by the probability that the action of the rays in the two cases must be very similar. Roentgen therapy for anuria complicating acute nephritis cannot yet be regarded as firmly established, because too few cases have been reported to permit one to draw conclusions. I only use it as an example of misinterpretation of the probable action of the rays.

As everyone knows, I have been rash enough to advance a theory to explain the action of roentgen rays or radium on acute and chronic inflammation, and have attempted to set forth this explanation in several papers published since 1926. This theory, which is not original, but which has been held by others, such as Pordes,[21,22] is based on an extensive analysis and correlation of the results of numerous experiments on animals and of a goodly number of clinical observations by radiologists of large experience. I shall not undertake to restate this explanation in detail; I shall only recall its main points.

The exceptional radiosensitiveness of leukocytes, especially of lymphocytes, polymorphonuclear leukocytes and eosinophils, is too well established to be subject to question. In many varieties of acute inflammation, it is well known that leukocytic infiltration is a more or less prominent feature of the inflammatory process. Besides leukocytic infiltration, the only other features commonly present in such lesions are hyperemia and edema. These two last features involve an increase in arterial circulation (an influx of blood) through and around the blood vessels into the surrounding tissues, on the one hand, and the exudation of serum from the blood vessels into the surrounding tissues, on the other hand. It must therefore be admitted that, aside from the erythrocytes, leukocytes and platelets brought to the inflamed tissues by the increased flow of blood, the two other factors (hyperemia and edema) are noncellular factors, because they consist only of the liquid portion of the blood.

When acute inflammatory processes, such as furuncles, carbuncles, abscesses, erysipelas, parotitis, sinusitis, otitis media, pneumonia (especially delayed resolution in lobar pneumonia) are exposed early enough to a small dose of roentgen rays, this exposure is followed in a large proportion of cases by rapid diminution of pain and by resolution of the inflammation without suppuration. When the affected area is exposed to a similar dose after suppuration has started, pain is relieved more slowly and suppuration is accelerated. When the inflammatory lesion is treated after suppuration has reached an advanced stage, little or no change in the course of the process can be perceived. Now, the rate at which the alterations mentioned occur after irradiation corresponds closely to the rate at which lymphocytes, polymorphonuclear leukocytes and eosinophils are known to be affected after irradiation of normal animals.*

How can so many different kinds of acute inflammation be influenced at the same general rate by a given dose of rays, unless the lesions contain a common factor and unless this factor is quite sensitive to irradiation? Since the outstanding effects of irradiation are exerted on cells, since the

* This agrees with the rate at which similar cells of human beings are influenced by irradiation. This influence consists in the destruction of a proportion of leukocytes varying with the dose of rays, within certain limits.

sensitiveness of cells to irradiation is known to be specific (specific range) for each variety of cells, and since the kinds of leukocytes mentioned are the only cells in the body whose sensitiveness to irradiation corresponds to that of acute inflammations it would seem difficult to conclude otherwise than that the major effect of irradiating such lesions is the destruction of a proportion of the leukocytes infiltrating the inflamed tissues, of those circulating in the blood stream through and around these tissues, and of the liberation of the contents of the destroyed leukocytes (antibodies, ferments, and so forth) into these tissues and into the blood stream itself.

As for chronic inflammations which are known to be amenable to irradiation, such as many skin diseases; tuberculous adenitis, peritonitis, synovitis, keratitis and iritis; actinomycosis, and many others, the pathologic circumstances are known to differ in that leukocytic infiltration is less prominent, but another more or less pronounced feature is proliferation of connective tissue. In comparison with leukocytes, connective tissue cells have such a low grade of sensitiveness to irradiation that they must be classed among the resistant cells. In chronic inflammatory lesions, therefore, we have one factor, proliferation of connective tissue, which would tend to diminish or retard the action of the rays. The interesting thing is that this is exactly what is observed in practice. The earlier chronic inflammations are treated, the better they respond, and *vice versa*. Moreover, the treatment must be repeated and larger doses are required to obtain a cure or maximal improvement.

Not long ago, I received from a rather well known radiologist a letter in which he expressed his inability to accept these ideas and in which he stated: "I realize, of course that the literature is replete with statements that x-rays readily disintegrate leukocytes. I have never been able to corroborate these statements myself, nor have any other workers conducting similar experiments in other laboratories and with whom I have spoken on the subject."

Now it is not a question of the literature being "replete with statements" that counts. If the evidence available consisted only of statements that "x-rays readily disintegrate leukocytes," it would not be worth considering. There is a great deal of much more substantial evidence in the form of results obtained from experiments on animals by Heineke (1903, 1904, 1905), Aubertin and Beaujard (1904), Helber and Linser (1905), Warthin (1906), Krause and Ziegler (1906), Benjamin, von Reusz, Sluka, and Schwarz (1906), Aubertin and Delamarre (1908), Fromme (1917), Hall and Whipple (1919), Taylor, Witherbee and Murphy (1919), Hartmann (1920), Leitch (September, 1921), Russ (October, 1921), Jolly (1924), Tsuzuki (1926), Piepenborn (1929), and from those of Rudberg (1907) and of Regaud and Crémieu[23–27] (1911–1912) on the thymus gland, which clearly shows the exceptional sensitiveness of lymphocytes. Many other experiments, although not directed primarily at lymphoid structures, have incidentally shown the same sensitiveness of lymphocytes, polymorphonuclear leukocytes and eosinophils. As for clinical evidence, how about the effect on the leukocytes in the circulating blood of irradiating the spleen in myeloid leukemia or the lymph nodes in lymphatic leukemia?

If the writer of that letter had read and correlated all this experimental and clinical evidence, I do not understand how he could have failed to be convinced of the great sensitiveness to irradiation of the varieties of leukocytes mentioned. If he has undertaken similar experiments himself, and has failed to obtain similar results, I should be inclined to suspect an essential difference in his experimental conditions. As for the "other workers conducting similar experiments in other laboratories," whom he mentioned in his letter, where have they published the technical details and results of their experiments? Perhaps an analysis of these reports might give a clue to the reasons for any discrepancy be-

tween their results and those which I have cited.

Further in the same letter the writer stated: "My impressions both clinically and experimentally are that the benefits to be expected from irradiation in the treatment of acute inflammatory conditions vary, not as the intensity of leukocytic infiltration at the moment of treatment, but rather as the intensity of the acute vascular congestion—edema—present at the time; in other words, that such benefits are more apt to accrue in the face of a predominantly congestive phase rather than in a predominantly suppurative phase of inflammation."

That statement is not as clear as it might be. In the first part, the writer does not believe that the favorable action of irradiation is related to the intensity of leukocytic infiltration at the moment of treatment, and this may well be true. No one, to my knowledge, has furnished good experimental evidence of a clear relationship between the *intensity* (or degree) of leukocytic infiltration and the favorable action of irradiation. But even if such an absolute relationship did not exist between the number of infiltrating leukocytes in an acute inflammatory lesion and the favorable effect of irradiation, that does not prove that the main action of the rays is not to destroy leukocytes infiltrating or circulating through the inflamed tissues. Other still obscure factors might prevent an absolute or proportional relationship between the number of infiltrating leukocytes and the effect of the rays.

His impression that the benefits to be expected from irradiation vary, not as to the degree of leukocytic infiltration but rather as to the intensity of acute vascular congestion and edema, apparently means that, in his belief, the rays act on the fluid part of the blood circulating as such through the inflamed tissue or on the serous fraction which has exuded from the vessels into the tissue in the form known as "edema." If this were true, the action of the rays would be a chemical or physicochemical action. But where is the experimental or clinical evidence to substantiate this idea? I am not aware of any. On the contrary, the existing evidence strongly favors the conclusion that roentgen rays and radium act primarily on the cells and only secondarily on the liquid part of the blood and on the body fluids.

His last statement, in which he expresses the belief that the benefits of irradiation are more likely to accrue in the congestive rather than in the suppurative phase of inflammation is in accord with my own clinical observations. This, however, does not influence the main argument, and certainly does not support, except superficially, the idea that the rays act primarily or principally on the fluid part of the blood or on exuded body fluids. I have repeatedly stated that, when an acute inflammatory lesion is irradiated after the onset of suppuration, the favorable effect of the rays is slower and not so striking, and that it tends to hasten the suppurative process. For some obscure reason, the presence of pus, undrained pus, diminishes the sensitiveness to irradiation of lymphocytes at least, and probably of other leukocytes also. I have seen this repeatedly in lymphoblastoma complicated by secondary infection. Before the pus was drained, the enlarged lymph nodes regressed very little after irradiation, but after adequate drainage had been provided, the lymph nodes recovered their usual sensitiveness to irradiation.

Certainly, there are factors connected with the action of the rays on inflammatory conditions which are still far from clear, but if the existing evidence is carefully considered, it is difficult to escape the conclusion that the rays act primarily on the infiltrating or circulating* leukocytes, or both.

REFERENCES

1. Aubertin, C., and Beaujard, E. Modifications immédiates du sang leucémique sous l'influence de la radiothérapie. *Compt. rend. Soc. de biol.*, 1904, *56*, 982–984.

* Circulating through and around the inflamed region.

2. Aubertin, C., and Delamarre, André. Action du radium sur le sang. *Compt. rend. Soc. de biol.*, 1908, *64*, 437–439.
3. Benjamin, E., von Reusz, A., Sluka, E., and Schwarz, Gottwald. Beiträge zur Frage der Einwirkung der Röntgenstrahlen auf das Blut. *Wien klin. Wchnschr.*, 1906, *19*, 788–794.
4. Cochard, Maurice. La radiothérapie du trachome. Thèse de Lyon, 1921.
5. Fromme, Georg. Ueber die allgemeine Wirkung der Röntgen- und Radiumstrahlen. *Ztschr. f. Geburtsh. u. Gynäk.*, 1917, *79*, 579–613.
6. Hall, C. C., and Whipple, G. H. Roentgen-ray intoxication; disturbances in metabolism produced by deep massive doses of the hard roentgen rays. *Am. J. M. Sc.*, 1919, *157*, 453–482.
7. Hartmann, A. Ueber die Einwirkung von Röntgenstrahlen auf Amphibien-larven; Einwirkung geringer Strahlendosen auf des Blutbildende Gewebe von Rana temporaria-larven. *Arch. f. Entwicklungsmechan. d. Organ.*, 1920, *47*, 131–209.
8. Heidenhain, L., and Fried, C. Röntgenbestrahlung und Entzüngdung. *Arch. f. klin. Chir.*, 1924, *133*, 624–665.
9. Heidenhain, L., and Fried, C.: Röntgenstrahlen und Entzündung. *Klin. Wchnschr.*, 1924, *3*, 1121–1122.
10. Heineke, H. Ueber die Einwirkung der Röntgenstrahlen auf Tiere. *München. med. Wchnschr.*, 1903, *1*, 2090–2092.
11. Heineke, H. Zur Kenntnis der Wirkung der Radiumstrahlen auf tierische Gewebe. *München. med. Wchnschr.*, 1904, *2*, 1382–1384.
12. Heineke, H. Experimentelle Untersuchungen über die Einwirkung der Röntgenstrahlen auf innere Organe. *Mitt. a. d. Grenzgeb. d. Med. u. Chir.*, 1904–1905, *14*, 21–94.
13. Helber, E., and Linser, P. Experimentelle Untersuchungen über die Einwirkung der Röntgenstrahlen auf das Blut. *München. med. Wchnschr.*, 1905, *1*, 689–691.
14. Jolly, J. Sensibilité comparée des différents organes lymphoïdes aux rayons X. *Compt. rend. Soc. de biol.*, 1924, *91*, 354–356.
15. Krause, P., and Ziegler, K. Experimentelle Untersuchungen über die Einwirkung der Röntgenstrahlen auf tierisches Gewebe. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1906, *10*, 126–182.
16. Leitch, Archibald. The immediate effects of X rays on the blood lymphocytes. *Arch. Radiol. & Electroth.*, 1921, *26*, 122–128.
17. Meldolesi, G., and Sabbadini, D. Sulla terapia del tracoma con le radiazioni secondarie ottenute col metodo del Ghilarducci. *Radiol. med.*, 1923, *10*, 222.
18. Piepenborn, Jürgen. Versuche über den Wirkungsgrad von Röntgenstrahlen verschiedener Wellenlänge auf die Milz der Maus, bei gleicher Dosis, gemessen in R-Einheiten. *Strahlentherapie*, 1929, *33*, 322–337.
19. Pordes, Fritz. Ueber die Natur der Wirkung der Röntgenstrahlen, speziell über das Verschwinden von Anurie nach Nierenbestrahlung. *Wien. klin. Wchnschr.*, 1923, *36*, 656–657.
20. Pordes, Fritz. Der Mechanismus der Röntgenwirkung; ein Erklärungsversuch. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1923–1924, *31*, 287–297.
21. Pordes, Fritz. Über Röntgenbehandlung entzündlicher Erkrankungen; Allgemeines und Spezielles. *Strahlentherapie*, 1926, *24*, 73–86.
22. Pordes, Fritz. Die Verlaufsänderung akuter Entzündungen nach Röntgenbestrahlung. *Strahlentherapie*, 1929, *33*, 147–151.
23. Regaud, Claude, and Crémieu, R. Évolution des corpuscules de Hassall dans le thymus röntgénisé du chat; mécanisme de l'accroissement de ces corpuscules. *Compt. rend. Soc. de biol.*, 1911, *71*, 325–328.
24. Regaud, Claude, and Crémieu, R. Sur l'involution du thymus produite par les rayons X; résultats expérimentaux; déductions thérapeutiques. *J. de physiothérapie*, 1912, *10*, 20–32.
25. Regaud, Claude, and Crémieu, R. Sur la suppression définitive de tissu thymique par la röntgenthérapie. *Compt. rend. Soc. de biol.*, 1912, *72*, 523–525.
26. Regaud, Claude, and Crémieu, R. Données relatives aux petites cellules ou lymphocytes du parenchyme thymique, d'après les résultats de la röntgénisation du thymus, chez le chat. *Compt. rend. Soc. de biol.*, 1912, *72*, 253–256.
27. Regaud, Claude, and Crémieu, R. Fondements expérimentaux de la röntgenthérapie appliquée à l'hypertrophie du thymus. *Arch. d'élect. méd.*, 1912, *21*, 481–499.
28. Rudberg, Hans. Studien über die Thymusinvolution: I. Die Involution nach Röntgenbestrahlung. *Arch. f. Anat. u. Entwicklungsgesch.*, Suppl. Bd. 1907, 123–174.
29. Russ, S. The immediate effects of X rays on the blood lymphocytes. *Arch. Radiol. & Electroth.*, 1921, *26*, 146–149.
30. Sabbadini, D. Le modificazioni cliniche ed anatomo-pathologiche della congiuntiva tracomatosa in seguito all'azione delle radiazioni secondarie. *Arch. di radiol.*, 1926, *2*, 584–688.
31. Stephan, Richard. Über die Steigerung der Zellfunktion durch Röntgenenergie. *Strahlentherapie*, 1920, *11*, 517–562.
32. Taylor, H. D., Witherbee, W. D., and Murphy, J. B. Studies on x-ray effects: I. Destructive action on blood cells. *J. Exper. Med.*, 1919, *29*, 53–73.

33. Thielemann, Rudolf. Zur Wirkungsweise des Radiumbestrahlung auf die trachomatöse Bindehaut. *Ztschr. f. Augenh.*, 1905, *14*, 559–569.

34. Tsuzuki, Masao. Experimental studies on the biological action of hard roentgen rays. Am. J. Roentgenol. & Rad. Therapy, 1926, *16*, 134–150.

35. Warthin, A. S. An experimental study of the effects of Röntgen rays upon the blood-forming organs, with special reference to the treatment of leukemia. *Internat. Clin.*, 1906, *4*, 243–277.

DISCUSSION

Dr. Benjamin H. Orndoff, Chicago. This paper from Dr. Desjardins, as well as many others, affirms the valuable part he has contributed to the field of therapeutic irradiation of inflammatory diseases. Notwithstanding the fact that many valuable papers have been published in medical literature at quite regular intervals from the beginning, roentgen therapy of inflammatory diseases is not generally understood and practiced by the medical profession.

From a consideration of the results I have observed in a fairly large series of cases, covering a rather wide variety of conditions, it seems fair to state that therapeutic results from roentgen irradiation of inflammatory conditions more than rival the results obtained in other fields of roentgen therapy. Reports from radiologists concerning their experience in this field of therapy are uniformly favorable.

Restricted use of irradiation in treating inflammatory diseases is corrected where the radiologist assumes the responsibility for the care and management of the cases. Obviously, it is unwise to attempt to confine the entire treatment to irradiation for any group of inflammatory diseases. Surgery, preferably electrosurgery, and radiotherapy should supplement one another along with other medical measures. A favorable response to irradiation constitutes in many cases an outstanding and somewhat spectacular clinical event.

It is indeed impressive to see an acute or subacute inflammatory condition change within an hour or two after irradiation. The symptoms of apathy, pain and hyperpyrexia reducing, the sense of well being and appetite returning, and in twenty-four or forty-eight hours the patient well out of danger and recovering.

In this communication and many others, Dr. Desjardins has called attention to the local and general defense mechanism created and activated by anti-inflammatory irradiation. There can no longer be doubt about the presence of a favorable clinical response, both local and general, following the proper irradiation of suitable cases, but the process going on in the tissues and in the body generally by which this is accomplished remains more vague and hypothetical. However, Dr. Desjardins has elucidated this phenomenon since 1926, and his conclusions seem plausible and they have been generally accepted.

Vol. 44, No. 4

A COMPARISON OF SKIN REACTIONS PRODUCED BY 200 KV. AND 1,000 KV. RADIATIONS*

By ROBERT S. STONE, M.D., *and* J. MAURICE ROBINSON, M.D.
Division of Roentgenology, University of California Medical School
SAN FRANCISCO, CALIFORNIA

1. OBJECT OF STUDY

ALTHOUGH roentgen rays generated by kilovoltages above the 200 range have been used for several years, there is still uncertainty as to whether the skin reactions caused by these rays are the same as those produced by 200 kv. radiations. Since the skin reaction has been accepted as a measure of biological effectiveness, it would appear to be important to know if one can obtain similar skin reactions by the use of two widely different qualities of high voltage radiations. Numerous clinical radiologists maintain that they can give a decidedly larger dose of higher voltage radiations to produce the same skin effect. They do not make it clear what they mean by "dose." They apparently disregard the fact that it is not the dose as measured in roentgens which is important, but the effect produced. Treatments that produce the same effect should be considered biologically equivalent regardless of the number of roentgens involved. This present study was undertaken in an attempt to determine whether or not similar skin reactions could be produced by 200 and 1,000 kv. radiations.

2. METHOD

The method used in the present study was to treat opposite sides of the same individual in as nearly corresponding areas as possible with the two qualities of radiation available. Patients with pelvic cancer were chosen as each side of the pelvis could be cross-fired separately. Each patient was treated daily except Sundays and holidays. One day the right half of the pelvis was treated front and back with 200 kv. The next day the left half was treated front and back with 1,000 kv. radiations, and so on through the course, alternating daily. By this method the opposite sides of the same patient could be compared no matter what the thickness of the patient or the size of the fields used. By comparing the two areas on the same individual the factor of different sensitivity of different skins was entirely eliminated.

From previous experiences of our own and others we chose 200 r measured in air, front and back, as the fractional dose to be used with the 200 kv. radiations. All but two of the patients were given this amount. With 1,000 kv. the fractional amount was varied for each group of patients, starting with 230 r in air and increasing for each succeeding group to approximately 250, 275 and 300 r. The first dose on each side was about one-half of the succeeding doses. The dose in roentgens was measured with a Victoreen condenser r meter (thimble chamber).

The 200 kv. apparatus was a Kelley-Koett constant potential generator activating an oil-cooled General Electric XPT tube (not shock-proof) operating at 15 ma. The radiations were filtered through the tube wall, said to be 0.2 mm. Cu equivalent, plus a filter of 0.5 mm. Cu + 1 mm. Al. The measured half-value layer of this radiation was 1.05 mm. Cu. The 1,000 kv. apparatus was a Sloan high frequency generator with a tungsten target. The radiations from this apparatus were filtered through the tube wall (1.5 mm. Cu + 3 mm. steel) and a filter of 2.0 mm. Pb + 0.2 mm. Sn + 1 mm. Cu + 1.5 mm. Al. The measured half-value layer of this radiation was 9.5 mm. Cu or 3.2 mm. Pb. In both instances the target skin distance was 80 cm. with the exception of a few cases treated at 70 cm. on the 1,000 kv. apparatus. The r per minute

* This study has been aided by grants from the Christine Breon Fund for Medical Research, and the Anna Fuller Fund.

output of the two tubes was about the same, 25 r (measured in air) on the 1,000 kv. apparatus, 21.3 r (measured in air) on the 200 kv. apparatus. The r per minute on the skin varied with the size of the field. In all but one instance the fields were 10 by 15 cm. in size and for this size the r per minute on the skin was 27 for 1,000 kv. and 29 for 200 kv. The r per minute on the skin at the point of exit varied with the size of the fields and the thickness of the part.

The doses given on the 1,000 kv. apparatus were controlled by a Victoreen integron calibrated daily with a Victoreen condenser r meter using the 250 r chamber. The doses given on the 200 kv. constant potential apparatus were controlled by time, milliamperage and pre-reading voltage. This apparatus was calibrated at intervals with the same Victoreen condenser r meter as was used on the 1,000 kv. apparatus. The calibration was found to be quite uniform. The roentgens in air were the only ones measured during the treatment. The roentgens on the skin and the exit dose were calculated from measurements made on limited presdwood phantoms.

It is recognized that, strictly speaking, roentgen or r applies only to measurements made in air and that "dose" applies only to amounts on the skin or in the tissues. For simplicity of expression, the measurements made with the Victoreen condenser r meter at any point are recorded as roentgens and the amount of the measurement is called the dose. In each instance the location of the point of measurement is given.

The skin reactions were recorded at various times during their evolution by means of color photographs. The lighting, exposure time and processing of the films have varied with resultant varying color effects from time to time. This does not invalidate the results since *the comparison is between opposite sides on the same photograph.* By this method we have been able to avoid the subjective element of observation and can present the results for others to see. We have found in the past that even when using the same quality of radiation on the opposite sides of the body with as nearly the same doses and spacing of doses as possible, there were slight variations in the reactions produced. This may be due to slight unrecognized differences in the doses, to slightly different spacing due to Sundays or holidays falling at different time intervals on the opposite sides, or to varying amounts of gas in the bowel at different times. The fact that there are such variations indicates that in the test cases slight variations cannot be given too great importance.

Because of physical condition the pressure of the cone of the 1,000 kv. apparatus was usually greater than that of the 200 kv. apparatus. This might have some effect on the upper parts of the fields, but not on the groins where no pressure was applied.

The patients in the present series have been followed for a few months only and so the statements apply to immediate reactions. A follow-up of patients treated four and five years ago with heavy doses of 800 kv. radiations shows that they develop the same late telangiectasis, cutaneous and subcutaneous fibrosis (leather skin) and keratoses as follow heavy doses of 200 kv. radiations. The statement "almost equal reactions" means that the erythemas appeared at the same time after starting treatment, developed to the same depth of color and receded at the same rate; that pigmentation appeared, developed and faded at the same rate and to the same degree; that any blistering was about the same on the two sides; that peeling was the same; and that the subjective symptoms were the same.

3. MATERIAL

The clinical material is divided into four general groups: (*a*) 7 patients with almost equal reactions; (*b*) 3 patients with slightly greater reactions on the 200 kv. side; (*c*) 2 patients with much greater reactions on the 200 kv. side; and (*d*) 6 patients with slightly greater reactions on the 1,000 kv. side.

Where the term skin reactions is used it

refers to the reaction over the anterior fields including the skin over the groin and lower abdomen. The posterior surface reactions are discussed separately.

The amount of radiation was calculated in each case for: (1) the roentgens as measured in air; (2) the roentgens in air plus the calculated back-scatter for the field size used, called "r on skin"; (3) the "total skin dose" which included the "r on skin" plus the exit dose. For the purposes of comparison percentage ratios were established by considering the 200 kv. amounts in each instance as 100 per cent and finding the percentage of this for the 1,000 kv. dose. Table I shows such a calculation for the single treatments given to one of the patients 14 cm. thick and with fields 10 by 15 cm. in size. From this it is seen that the 1,000 kv. dose is a different percentage of the 200 kv. dose for each measurement. Thus it is 137 per cent of "air r" dose, 110 per cent of the "skin r" dose and 123 per cent of the total skin dose. We believe that the "total skin dose" is the most accurate means of comparison and so have used it as our basis, but we discuss the other figures as well.

The patients in Group I (Table II) all showed essentially similar skin reactions on the two sides (Figs. 1–4). They were all given 200 r in air as fractional doses to a total of 2,300 r in twelve sittings with the 200 kv. apparatus; and 275 r in air as fractional doses to a total of 3,125 or 3,162 r in twelve alternating sittings with the 1,000 kv. apparatus. The fact that the total dose does not equal the fractional dose multiplied by the number of sittings is explained by the fact that the first dose was about one-half of the succeeding ones. The 1,000 kv. air r doses were 136 per cent of the 200 kv. air r doses. The back-scatter in a field 10 by 15 cm. in size is 36 per cent for the 200 kv., and 9 per cent for the 1,000 kv.

TABLE I

ILLUSTRATING THE METHOD OF CALCULATING DOSAGE

E.C. Age 32. 14 cm thick.
Four 10×15 fields, 12 treatments to each in 29 days.
One day, rt. front and back —200kv
Alternate day, lt. front and back—1000kv

	Per Treatment		Total	
	200kv	1000kv	200kv	1000kv
(1) r in air	200	275	2300	3162
Backscatter	36% 72	9% 25	828	284
(2) r c.b.s	272	300	3128	3446
Exit dose	17% 46	31% 93	532	1069
(3) Total skin dose	318	393	3660	4515

Ratio $\frac{200kv}{1000kv}$ (1) in air $\frac{100}{137}$, (2) c.b.s. $\frac{100}{110}$, (3) total skin dose $\frac{100}{123}$

TABLE II

GROUP I

Skin Reactions—similar

Percentage doses are 1,000 kv. doses as per cent of 200 kv. doses
All fields 10×15 cm. in size

Case	Thick cm.	No. Treatments Each Field	Elapsed Days	Total r Air		Air r per cent	Total r with Back-scatter		r Skin per cent	Total r Skin Dose		Total Skin per cent
				200 kv.	1000 kv.		200 kv.	1000 kv.		200 kv.	1000 kv.	
E. B.	14	12	27	2300	3125	136	3128	3406	109	3660	4462	122
E. C.	14	12	29	2300	3162	137	3128	3446	110	3660	4515	123
S. H.	14	14	32	2300	3125	136	3128	3406	109	3660	4462	122
M. R.	16	12	27	2300	3162	137	3128	3446	110	3503	4308	123
A. A.	16	12	29	2300	3162	137	3128	3446	110	3503	4308	123
J. M.	15	12	30	2300	3125	136	3128	3406	109	3565	4360	122
C. M.	15	12	30	2300	3125	136	3128	3406	109	3565	4360	122

TABLE III

Skin Reactions—200 kv. more marked

Percentage doses are 1,000 kv. doses as per cent of 200 kv. doses

Fields 10×15 cm. except J. R., 10×20 cm.

Case	Thick cm.	No. Treatments Each Field	Elapsed Days	Total r Air		Air-per cent	Total r with Back-scatter		r Skin per cent	Total r Skin Dose		Total Skin per cent
				200 kv.	1000 kv.		200 kv.	1000 kv.		200 kv.	1000 kv.	
GROUP II												
M. S.	16	13	31	2479	3016	122	3383	3288	97	3823	4110	107
L. G.	16	14	33	2635	3333	126	3584	3633	101	4050	4541	112
J. R.	18	15	36	2900	3623	125	4060	3985	100	4466	4862	109
GROUP III												
H. C.	18	16	40	3627	3550	98	4951	3862	78	5446	4636	85
E. S.	20	14	32	3159	3090	98	4283	3362	79	4612	3943	85

radiations, resulting in the "r on skin" for the 1,000 kv. radiations being 3,406 which is 109 per cent of the 3,128 skin r for the 200 kv. radiations. The exit doses varied with the thickness of the patient. These were all 14 to 16 cm. thick with the exit dose from the 200 kv. radiations varying from 12 to 17 per cent and that from the 1,000 kv. varying from 25 to 31 per cent. Thus the total skin doses of the 1,000 kv.

Figs. 1–6 (see opposite page)

Comparison of skin reactions produced by radiations of widely different quality: 200 kv. on right side, 1,000 kv. on left side. Black crusts caused by application of 10 per cent tannic acid solution to blistered areas.

FIG. 1. S. H. (see Table II). Three stages in evolution of *equal* skin reactions; 22 per cent more roentgens in total skin dose of left side. *A*, thirty-five days after beginning treatment, six days after end of treatment; reactions quite equal. *B*, forty-two days after beginning treatment, thirteen days after end of treatment; still equal. *C*, sixty-five days after beginning treatment, thirty-six days after end of treatment. Both sides have recovered at the same rate and to the same degree.

FIGS. 2, 3 and 4. Single stages in evolution of *equal* skin reactions. Three patients treated the same as S. H. (Fig. 1) (see Table II). Note that there is more striking similarity between reactions of skin of same individual to different qualities of radiation than there is between skin reactions of different individuals treated alike with same quality whether 200 or 1,000 kv.

FIG. 2. E. C., thirty-one days after beginning of treatment, two days after end of treatment; 23 per cent more roentgens in total skin dose on left side; skin reactions about equal. (Other stages were also equal.)

FIG. 3. E. B., thirty days after beginning of treatment, three days after end of treatment; 22 per cent more roentgens in total skin dose on left side; more extensive blistering on left; otherwise reactions very similar. (Later stages about equal on both sides.)

FIG. 4. J. M., thirty-seven days after beginning of treatment, seven days after end of treatment; 22 per cent more roentgens in total skin dose on left side. Skin reactions practically equal. (Other stages were also about equal.)

FIG. 5. L. G. (see Table III). A stage in evolution of *greater* skin reaction on *right* side (200 kv.). Only 12 per cent more roentgens in total skin dose on left. Forty-one days after beginning of treatment, seven days after end of treatment. Reaction on right developed sooner and is more marked, with blistering.

FIG. 6. L. S. (see Table IV). A stage in evolution of *greater* skin reaction on left side; 33 per cent more roentgens in total skin dose on left. Forty-five days after beginning of treatment, twelve days after end of treatment. More rapid development and progress on left. Compare Figures 5 and 6 with Figures 1 to 4 which show equal reactions when 25 per cent more roentgens were present in total skin dose on left side (1,000 kv.).

FIG. 1 *A*

FIG. 1 *B*

FIG. 1 *C*

FIG. 2

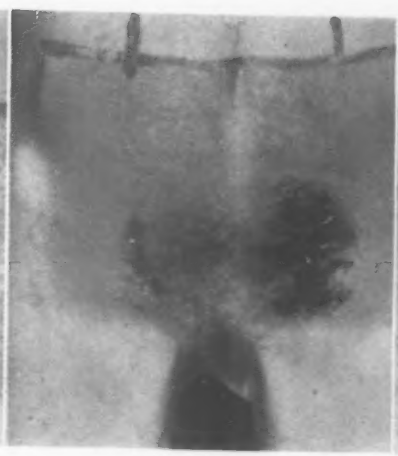


FIG. 3

FIG. 4

FIG. 5

FIG. 6

UNIV. OF MICH.

radiations were 122 and 123 per cent of that of the 200 kv. radiations. From this we can conclude that, allowing for biological inaccuracies, to produce similar skin reactions with these two qualities of radiation requires about 25 per cent more total skin dose of the 1,000 kv. rays.

The three patients in Group II (Table III) showed slightly more severe skin reactions on the side treated with the 200 kv. radiations. They were the 2 patients who were given the 200 kv. radiations in larger fractions, an average of 230 r (in air) per sitting. The 1,000 kv. radiations were given in approximately the same fractions so that the total air r doses were essentially the same on the two sides. One patient received approximately 3,100 r in thirty-two days and the other 3,600 r in forty days. In both cases the 200 kv. reactions were severe with blistering and peeling and late telangiectasis. The 1,000 kv. doses as percentages of the 200 kv. doses were: air r 98 per cent, r with back-scatter 78 per cent, total skin dose 85 per cent. From these it is obvious that the same doses as measured in roentgens in air result in very unequal skin reactions; that produced by the 1,000 kv. radiations being much less severe.

TABLE IV

GROUP IV

Skin Reactions—1,000 kv. slightly more marked

Percentage doses are 1,000 kv. doses as per cent of 200 kv. doses

All fields 10×15 cm. in size

Case	Thick cm.	No. Treatments Each Field	Elapsed Days	Total r Air		Air r per cent	Total r with Back-scatter		r Skin per cent	Total r Skin Dose		Total Skin per cent
				200 kv.	1000 kv.		200 kv.	1000 kv.		200 kv.	1000 kv.	
M. M.	20	13	32	2500	3700	148	3400	4033	119	3655	4719	129
I. S.	18	13	33	2500	3700	148	3400	4033	119	3740	4840	130
L. S.	16	13	33	2500	3700	148	3400	4033	119	3808	5051	133
E. F.	19	11	36	2100	3100	148	2856	3379	119	3113	4021	129
G. T.	16	13	29	2500	3700	148	3400	4033	119	3808	5051	133
E. N.	17	13	33	2500	3700	148	3400	4033	119	3797	5013	132

tions on the side treated with 200 kv. (Fig. 5). The fractional doses were roughly 200 r in air, 200 kv. and 250 r in air, 1,000 kv. The total doses in roentgens in air per patient were, giving the 200 kv. dose first, 2,479 to 3,116 r; 2,635 to 3,333 r and 2,900 to 3,623 r. Thus the 1,000 kv. doses measured by roentgens in air were 122, 125 and 126 per cent of the 200 kv. doses. By similar figuring as in Group I, the doses as measured with back-scatter of the 1,000 kv. radiations were 97, 100 and 101 per cent of the 200 kv. doses and the total skin doses were 107, 109 and 112 per cent. From this group it is apparent that giving approximately the same dose as measured in roentgens with back-scatter does not result in similar skin reactions but in a more severe reaction on the side treated with the 200 kv. radiations.

The 2 patients in Group III (Table III) showed much more severe reactions on the

The 6 patients in Group IV (Table IV) showed slightly more severe reactions on the side treated with the 1,000 kv. radiations than on the opposite side (Fig. 6). On the 200 kv. side they were given 200 r in air as fractional doses to a total of 2,500 r in 5 cases and 2,100 r in the sixth. On the 1,000 kv. side they were given 300 r in air as fractional doses to a total of 3,700 r in the 5 cases, and 3,100 r in the sixth.

The 1,000 kv. doses as average percent-

ages of the 200 kv. doses were: air r 148 per cent, r with back-scatter 119 per cent, total skin dose 130 per cent. The actual figures varied with the thickness of the patients. From these cases it is apparent that giving a total skin dose of 1,000 kv. radiations which is 30 per cent greater than that of 200 kv. radiations, as measured in roentgens by a thimble chamber, results in a slightly more severe skin reaction.

These four groups show that equal skin reactions can be produced by the two qualities of radiations and that either quality can be made to give a more severe reaction by giving a slightly larger biological dose of that quality.

4. DISCUSSION

It has been claimed by some radiologists that the skin reactions produced by radiations in the range above 200 kv. are not the same as those by 200 kv. radiations, and that the difference is due mainly to an inherent property of the radiations of that quality (wave length effect) rather than to the dose given. The cases presented show that skin reactions so nearly alike that no significant differences were detected can be produced on the lower anterior abdominal wall and in the groins with the two qualities of radiation under discussion. Such similar reactions must be produced by biologically equivalent doses, no matter what the variation in physical units. Since the difference lies not in the reactions obtained but in the statement of the number of roentgens used, a discussion of the method of stating dosages is in order. The method of obtaining the similar reactions needs also to be analyzed.

The doses in roentgens as measured by the thimble chamber that are required to produce these biologically equivalent reactions with the two qualities of radiations may be specified as: (1) roentgens in air, (2) roentgens with back-scatter, or (3) the total skin dose (the total of the roentgens with back-scatter and the roentgens measured at the point of exit). When roentgens as measured in air are considered, it requires (varying with the size of the field and the thickness of the part) about 40 per cent more of the 1,000 kv. radiations, whereas when the total skin dose is considered only 25 per cent more is needed. The difference between 40 and 25 is explained by the difference in back-scatter for the two qualities which is not offset by the difference in the exit dose. The back-scatter occurring in a field 10 by 15 cm. in size is 36 per cent of the r in air of the 200 kv. radiations used and only 9 per cent of those of the 1,000 kv. radiations (Fig. 7).

In figures, if one gives 200 r in air of 200 kv. and of 1,000 kv. radiations to fields 10 by 15 cm. in size, the r with back-scatter will be 272 and 218, respectively. To produce a skin measure of 272 r with 1,000 kv. radiations 250 r in air must be given [250+22 (9%) = 272]. To produce a skin measure of 272 r with 400 kv. radiations, using Glasser's[1] back-scatter measurements 227 r in air must be given [227+45 (20%) = 272]. *Thus those radiologists who have given the same number of roentgens in air on their higher voltage apparatus as they gave with their 200 kv. apparatus were actually giving considerably smaller skin doses and should expect less skin reaction.* When the additional 25 per cent differential is taken into consideration it is readily apparent that the skin reaction should be much less. The reactions in the skin of the patients in Group III above have demonstrated that when the same number of roentgens in air are delivered there is actually considerably less skin reaction to the 1,000 kv. radiations.

Nor is it enough to consider the dose in roentgens as measured with back-scatter, unless there is no cross-fire. The exit dose varies considerably with the two qualities here considered. When using fields 10 by 15 cm. in size on a patient 20 cm. thick the exit dose for the 200 kv. radiations 7.5 per cent of the r on skin, and for the 1,000 kv. radiations is 17 per cent (Fig. 8). This adds an appreciable amount to the skin and cannot be neglected. From all of these considerations we can conclude that the "total

skin dose" is the only accurate means of comparison, since it is the only measurement which includes all of the radiations acting on the skin.

Moreover it is important to notice that skin reactions may not be produced even though the total dose of the 1,000 kv. radiations is increased 25 per cent or more by giving additional fractions. Such doses are smaller fractions of total skin dose and do not represent biologically equivalent fractions. To properly compare different qualities of radiations the same biologically in order to produce the same skin reactions we gave equal fractions of the total dose of each quality of radiation at each sitting. That means that not only the total doses but also the fractional doses must be biologically equivalent. The total doses should be delivered in the same number of elapsed days. We did not give any patients the same total doses on the opposite sides with the different qualities of radiations in different periods of time. It is common knowledge, however, that giving smaller fractions over longer periods of time results in lesser skin reactions than giving larger fractions over shorter periods, even though the total doses are the same. It is to be expected that by giving the same fractional doses in air r or even in skin r with 1,000 kv. as with 200 kv. radiations the same equivalent fractions of the total dose must be given at each sitting, the sittings must be spaced the same way and the total dose must be given in the same total elapsed time.

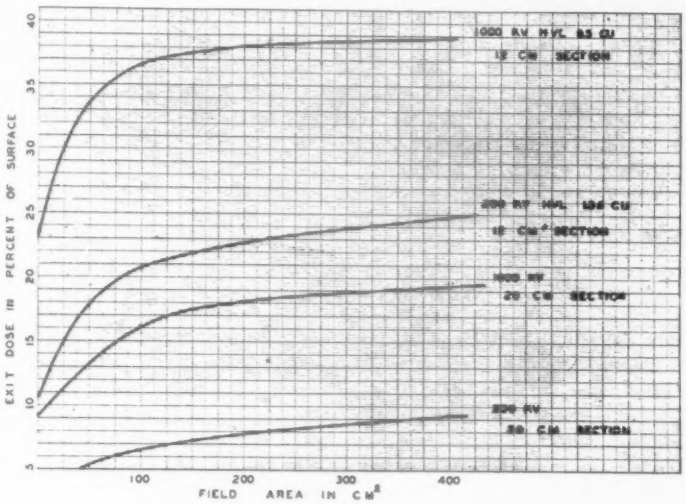


Fig. 8. Curves of exit doses for phantoms 12 cm. and 20 cm. thick.

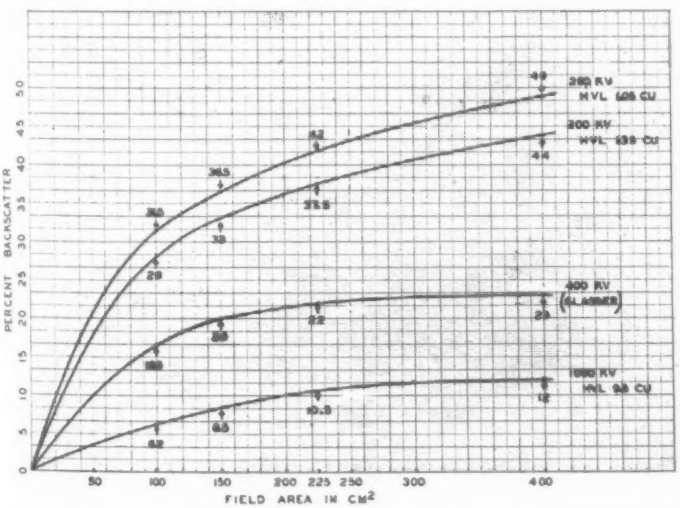


Fig. 7. Curves of percentage back-scatter for various voltages and field sizes.

We have no material to show the effect of varying the intensity (r/min.) on the reactions produced. We did not give the two qualities of radiations at exactly the same intensities, but we assume the slight difference to be negligible. The 1,000 kv. radiations were given, as stated above, at a slightly greater intensity as measured in air, but the result is a slightly lower intensity on the skin, 27 to 29. The r per minute of the exit doses was quite low with both qualities, but proportionately considerably higher from the 1,000 kv. radiations.

When all of these factors are taken into

consideration the cases presented show that to produce similar skin reactions there is still a 25 per cent increase in the total skin dose as measured in roentgens required of the 1,000 kv. radiations as compared with the 200 kv. radiations. There are two factors that may explain this. In the first place, the roentgen has a lower energy value in the range of the 1,000 kv. radiations than it has in the range of the 200 kv. radiations (Lauritsen[2]). Because of this it should require more roentgens as measured in 1,000 kv. beam to produce the same amount of ionization in the tissue and therefore the same biological effect. In the second place, we do not know as yet whether the thimble chambers of the Victoreen condenser r meters which were used accurately measure roentgens in the higher voltage beams. Some unpublished biological comparisons which we have made show that a given number of roentgens of 1,000 kv. radiations as measured by the thimble chamber have less effect on animal tumors than a similar number of roentgens of 200 kv. radiations. Some years ago Aebersold measured the beam of the California Institute of Technology roentgen-ray tube with our thimble chambers when it was operating at 800 kv. and they were measuring with an open air chamber. He found the thimble chamber to read considerably higher (more roentgens per minute) than the open air chamber in the same beam. We believe that the above factors may explain the observed differences and that a theory of a differential wave length effect need not be invoked.

Recently, Packard and Exner[3] have reported the results of measuring the effectiveness on *Drosophila* eggs of radiations from many kilovoltages up to 900, using a Victoreen condenser r chamber as control. They found that in roentgens as so measured 900 kv. radiations were only 80 per cent as effective as 200 kv. radiations. This means that 23 per cent more such roentgens of 900 kv. than roentgens of 200 kv. radiations must be given to produce the same biological effect. If their curve is continued out to 1,000 kv., 25 per cent more would be required. Their results and ours are therefore very much the same.

It should be emphasized that the 25 per cent correction applies to the total skin dose and that it is not possible to correct for the biological difference of the 1,000 kv. radiations by adding 25 per cent to the dose as measured in roentgens in air. The back-scatter and the exit dose vary with the size of the field used and the thickness of the part irradiated and so vary the relation between the total skin dose and the dose in roentgens in air. To use the same example as before, if 200 r in air were used with the 200 kv. radiations to fields 10 by 15 cm. in size on a patient 18 cm. thick the result would be: 200 r (air)+36 per cent back-scatter=272 r, adding 10 per cent exit=299 r total skin dose. On the 1,000 kv. apparatus, if 25 per cent were added to the air r dose of 200 on the assumption that it would give the proper correction then 250 air r would be delivered: 250 air r+9 per cent back-scatter=272 skin r; add 20 per cent for exit dose=326 r total skin dose. This 326 r is only 109 per cent of the 299 r calculated for 200 kv., a 9 per cent, not a 25 per cent, increase in total skin dose.

It would seem that if radiologists are interested in biological effect rather than in giving a certain number of roentgens they should cease making the loose statement that larger doses of so-called supervoltage radiation can be given with less skin effect. What is really meant by such a statement is that it takes a greater number of roentgens as measured by a thimble chamber to produce the same effect. If it takes more roentgens to produce the same effect on the skin, is it not likely that it would take more roentgens to produce the same effect on the tumor? It is false and misleading both to the laity and to other physicians and surgeons to speak of "larger doses." We should use the term "biologically equivalent" doses until the physicists provide us with a truly comparative measure to use on the various voltage radiations.

The same explanation probably applies

to the often repeated statement that there is less systemic reaction from radiations produced by kilovoltages above the 200 range. If biologically equivalent doses are given a biologically equivalent reaction should be and is, in our experience, obtained. *The same number of roentgens in air is a much smaller dose and therefore produces less radiation sickness.*

Since the depth dose is a percentage of the skin dose and NOT *of the air dose, similar air r doses result in lower depth doses of 1,000 kv. radiations, and therefore less diarrhea results.* It is hard to believe that with less reaction on the bowel there can be more reaction in the adjacent tumor.

We have discussed the reaction as found on the anterior abdominal wall. The reactions posteriorly over the sacrum and ilium differ somewhat. Here the back-scatter from the bones may play a part and add differing amounts for each quality of radiation used. In the cases discussed above it was found that even a 30 per cent increase in the total skin dose did not always produce the same reaction over the sacrum from the 1,000 kv. as from the 200 kv. radiations.

In a previous study of this subject by one of us (Stone[4]) a slightly different result was obtained. That study was based largely on a comparison of skin reactions on different patients, some treated with 200 kv. and others with 1,000 kv. Moreover, the r per minute and the elapsed days of the treatment period varied. The present study is more accurate in that the skin effects were compared on the same patients. The intensities of the two qualities of radiations and the elapsed days were more nearly equal. The color photography removed the subjective element of individual observation and prejeudice to a considerable degree and removed the necessity for comparing an observed reaction with the mental picture of a previous one.

We are not here concerned with the advantages or disadvantages of one or the other types of radiation. Our aim has been to show that biologically equivalent doses produce biologically similar reactions on the skin.

CONCLUSIONS

1. Similar skin reactions can be produced by 200 kv. and 1,000 kv. radiations on opposite sides of the abdomen of the same patient.

2. The similarity includes: (1) time of appearance; (2) degree of erythema; (3) extent of blistering and peeling; (4) degree of pigmentation; (5) subjective symptoms.

3. The physical doses as measured by a thimble chamber are not the same. It required approximately 25 per cent more roentgens in "total skin dose" of the 1,000 kv. radiations.

4. To produce these similar reactions the fractional doses as well as the total doses must be "biologically equivalent."

5. The distribution of the dose in days, and the total elapsed time must also be the same.

6. The difference in the number of roentgens, as measured by a thimble chamber, required to produce "biologically equivalent" skin reactions with the two qualities of radiation is approximately the same as that found by Packard using *Drosophila* eggs.

7. "Biologically equivalent" doses, merely because they require a greater number of roentgens of higher voltage radiations, should not be described as "larger doses."

REFERENCES

1. Glasser, Otto. Dosage measurements on ten 400 kv. roentgen-ray generators. Am. J. Roentgenol. & Rad. Therapy, 1937, *38*, 769–775.
2. Lauritsen, C. C. On the relation between the roentgen and the erythema dose. Am. J. Roentgenol. & Rad. Therapy, 1935, *33*, 235–236.
3. Packard, Charles, and Exner, F. M. Comparison of biological and dosimeter measurements at voltages from 200 to 1,000 kv. Read at Third International Cancer Congress, Sept. 12, 1939.
4. Stone, R. S. Skin reactions caused by 1,000 kilovolt and 200 kilovolt radiations. *Radiology*, 1938, *30*, 88–93.

COMPACT, SUPERVOLTAGE, ROENTGEN-RAY GENERATOR USING A PRESSURE-INSULATED ELECTROSTATIC HIGH VOLTAGE SOURCE

By J. G. TRUMP, D.Sc., R. J. VAN DE GRAAFF, PH.D., *and* R. W. CLOUD, M.S.
Massachusetts Institute of Technology
CAMBRIDGE, MASSACHUSETTS

THE 1.25-megavolt, roentgen-ray generator[1] recently developed by the Massachusetts Institute of Technology for cancer therapy at the Massachusetts General Hospital is described in this paper with particular reference to those aspects of the apparatus of interest to roentgenologists. The apparatus, which has been used at the Institute for physical studies of the radiation as well as for some therapy, is now being installed in the new White Memorial Building of the Hospital. A previous development—a 1-megavolt, air-insulated, roentgen-ray generator—has been in use for therapy at the Collis P. Huntington Memorial Hospital[2] in Boston since March 1, 1937. The present development is a continuation of the Institute's program of producing high-energy radiations with electrostatic high voltage sources and was undertaken with the object of producing a more compact source of such radiation through the use of compressed gas as the voltage insulating medium. A further object was the investigation of the factors involved in the design of pressure-insulated electrostatic generators, with a view to the later development of apparatus having still greater relative compactness as well as higher voltage.

ELECTROSTATIC HIGH VOLTAGE SOURCE

The electrostatic generator is of the belt type, in which electric charge is continuously transferred by a rapidly moving belt of insulating material to a high voltage terminal. This terminal may thus be maintained steadily at a high constant potential above ground by adjusting the current transferred by the belt to equal the current requirement of the roentgen tube plus the leakage current from the terminal to ground at that potential. The electrostatic generator and acceleration tube are contained within a vertical steel tank 34 in. in inside diameter and 100 in. in length. The tank, shown in Figure 1, is divided into three sections—the upper two being completely removable for accessibility to the apparatus within. The gap from terminal to tank, across which the entire voltage is insulated, is 5 in. at the sides of the terminal and about 7 in. at the top. The dome-shaped high voltage terminal is supported on an insulating column built up on successive metallic equipotential members separated by insulating disks. The total voltage between terminal and the ground plane is distributed uniformly along the column by the leakage current through high resistances connected between the column sections.

CHARGE CONVEYING SYSTEM

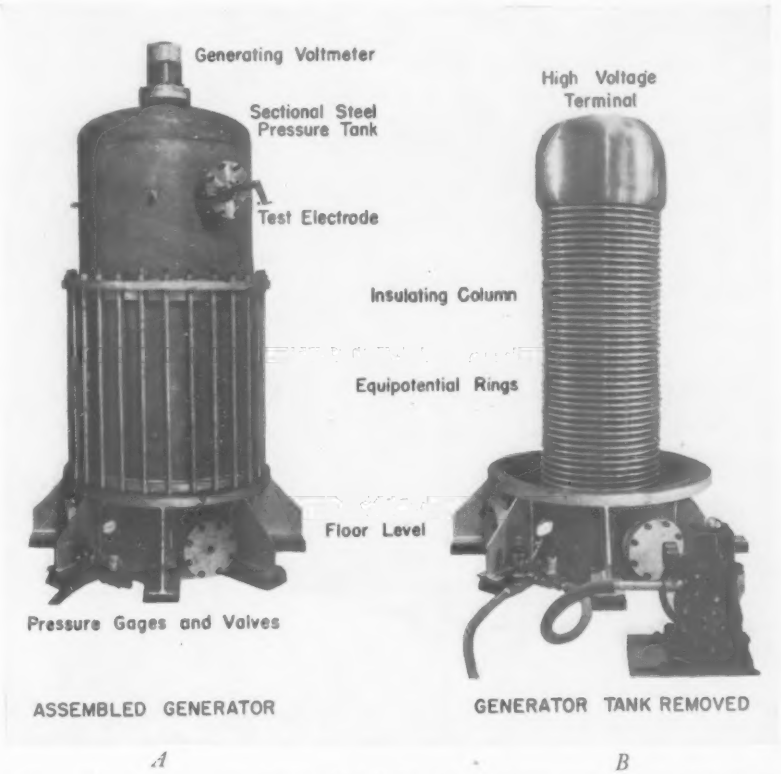
The electric charge is carried on a single three-ply rubber fabric belt 14 in. wide and running at 5,000 ft. per minute. This belt is driven by a 10-h.p., 3,450-rpm, 3-phase induction motor. Negative electric charge is sprayed on the belt at the lower grounded end from a row of corona points directed at the pulley and supplied with power from a controllable 40-kilovolt transformer rectifier unit. Within the high voltage terminal this charge is collected by the corona point collector, and serves to bring the insulated upper pulley to such a potential relative to the terminal that an equal amount of positive charge is sprayed from a second corona rod onto the downward run of belt. Thus both runs of the belt are effective in transferring electric charge to the terminal.

EFFECT OF GAS PRESSURE ON GENERATOR OUTPUT

A characteristic of electrostatic high voltage sources is that both the maximum voltage and current of a given machine may be increased by the simple expedient of increasing the dielectric strength of the medium in which the apparatus is housed. This can be done, for example, by increasing the pressure of the air, since in a uniform field the breakdown strength of gases increases nearly directly with the pressure. Figure 2 shows the manner in which both voltage and current of the pressure-insulated electrostatic generator increase with pressure. The machine is designed to operate normally in air at 10 atmospheres gauge pressure, and at this pressure will produce, with adequate margin for safety, 1,200 kilovolts with up to 1 milliampere on the roentgen-ray target. Though with freon (dichlorodifluoromethane) the same voltage and current are obtained at one-third the pressure required of air, the chemical instability of freon under the action of corona precludes its use for this application at the present time.

ROENTGEN TUBE

The roentgen tube is mounted within the insulating column of the generator and is built up of sixteen porcelain sections mounted vertically. The lower end of this porcelain assembly is attached to a steel tube which extends downward and out of the pressure tank into the treatment room where it terminates in a water-cooled, roentgen-ray target. The source of electrons is a 10-mil., spiral filament situated at the upper end of the porcelain assembly well within the high voltage terminal. The electron beam originating from this fila-



A *B*

FIG. 1. *A*, view of assembled generator. Over-all height above floor, 7 ft. Grounded end of roentgen tube (not shown) extends into treatment room below. *B*, view of generator with upper two pressure-tank sections removed.

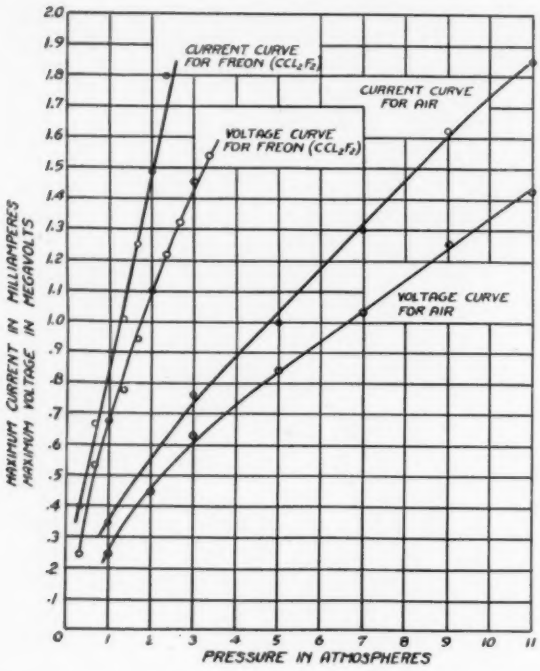

CURRENT CURVE FOR FREON (CCl_2F_2)
CURRENT CURVE FOR AIR
VOLTAGE CURVE FOR FREON (CCl_2F_2)
VOLTAGE CURVE FOR AIR
MAXIMUM CURRENT IN MILLIAMPERES
MAXIMUM VOLTAGE IN MEGAVOLTS
PRESSURE IN ATMOSPHERES

Fig. 2. The maximum voltage and current developed by the electrostatic generator at various pressures of air and of freon (dichlorodifluoromethane).

ment is progressively accelerated by means of hollow electrodes mounted between the porcelain sections, which derive their potential from the generator column.

The roentgen tube is continuously evacuated by a high speed, mercury vapor pumping system backed by a Hyvac pump. Mercury vapor is prevented from reaching the tube by means of a dry-ice trap which has sufficient ice capacity to last four days.

ROENTGEN-RAY TARGET

The roentgen-ray target (Fig. 3) consists of a gold, hemispherical spinning 2 in. in diameter, soft soldered onto a copper tube. A second copper spinning outside and spaced from the gold provides a water-cooling channel. The heat from the electron beam is therefore liberated within the gold and passes directly to the water. This construction, which avoids bonding the target to a dissimilar metal, appears to have advantages in simplicity and reliability. It moreover makes possible the reduction of the inherent filtration to a minimum when desired. The target assembly is insulated from the lower tube extension so that the electron current arriving at the target is measured by the milliammeter mounted on the control panel. The target end of the tube is shielded by 4 in. of lead with an opening at the bottom to define the roentgen-ray beam. This opening can be closed

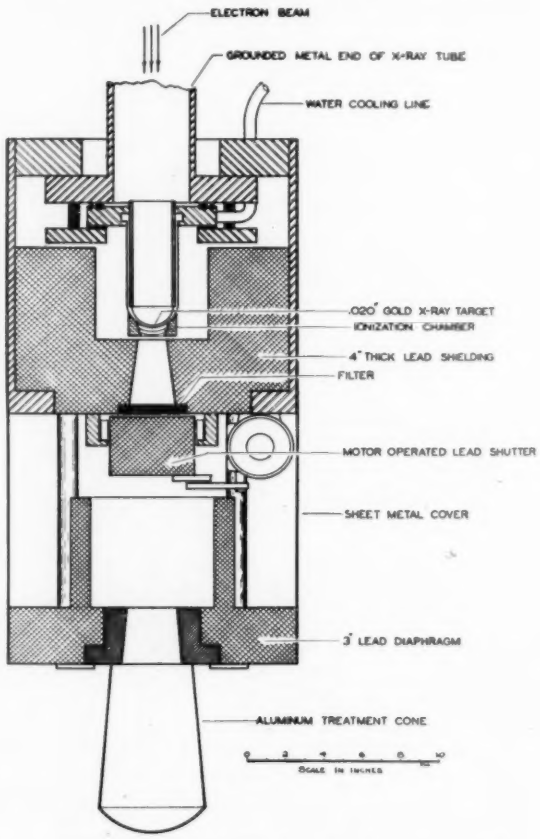


Fig. 3. Diagram of grounded end of roentgen tube showing target, lead shielding, shutter, and portal-defining lead diaphragms.

by a motor-driven lead shutter 3 in. thick, operated from the control panel. In order to secure accurate beam definition, the roentgen-ray beam is redefined by a 3-in. thick lead diaphragm 40 cm. below the target.

OPERATION

The generator can be completely controlled from the panel shown in Figure 4, which provides instruments for reading directly the target current, the voltage, the

ionization, and the time of treatment. The voltage is read by means of a generating voltmeter[3] of special design which provides a continuous and linear measure of the voltage. The output roentgen-ray intensity is measured by an air ionization chamber mounted directly below the target. The ionization at this point is sufficiently intense so that the current can be read directly on a panel-mounted instrument without amplification. By limiting the diameter of this ionization chamber to 1 inch, the instrument further indicates that the focal spot is properly centered. Operation of the lead shutter which defines the roentgen treatment also operates a timer so that the time of treatment may be accurately measured.

The routine operation of the roentgen-ray generator is essentially a one-control affair, since the current setting is ordinarily not adjusted for each treatment. The operating procedure is simply to increase the current carried on the generator belt by increasing the transformer-rectifier spray voltage until the desired operating voltage is reached, whereupon the shutter may be opened. This procedure ordinarily requires only a few seconds.

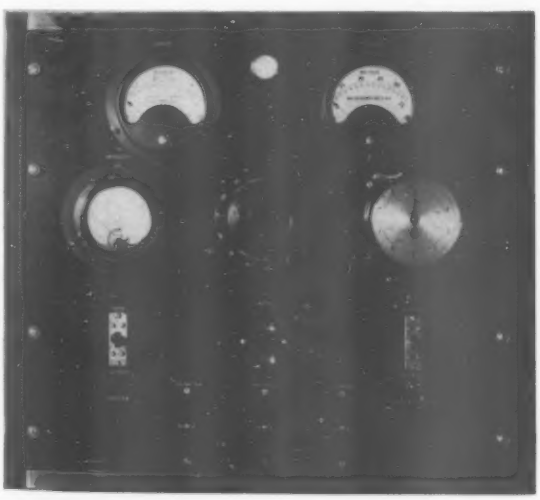


Fig. 4. Control panel of 1.25-megavolt, roentgen-ray generator.

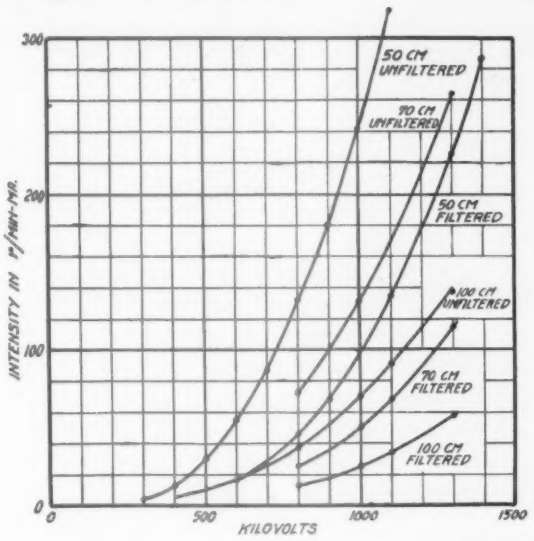


Fig. 5. Dependence of roentgen-ray output intensity on the generator voltage, the treatment distance, and the filtration.

ROENTGEN-RAY OUTPUT

Since the roentgen rays are produced by a constant potential source, it is to be expected that the output intensity per milliampere at any given voltage will be higher than for a-c or pulsating voltage sources. Figure 5 shows the rapid increase of roentgen-ray intensity with voltage, the measurement being made in free air with a 10 by 10 cm. field. The intensity was measured with a standard condenser type thimble chamber at distances 50, 70 and 100 cm. in the downard, or electron beam, direction from the target. The "unfiltered" radiation passed through the inherent filter of the target system consisting of 0.5 mm. Au, 1.25 mm. Cu, and 3 mm. H_2O. The "filtered" radiation passed through an additional 2 mm. Pb, 3.75 mm. Cu, and 2 mm. Al.

Analysis of the curves of Figure 5 shows that above 600 kv. the roentgen-ray intensity under the above conditions increases approximately as the 2.7 power of the voltage for the "unfiltered" radiation, and as the 3.2 power for the "filtered" radiation. The extremely rapid increase of intensity with voltage[4] permits the electrostatic generator operating above 1,000 kv. to produce considerable intensity with less than 1 ma. of

current on the target. For example, at 1,200 kv. the free air intensity at 70 cm., with a 10 by 10 cm. field, and filtered as above, is 45 r per minute at 0.5 ma. The treatments given at the Institute were under these conditions. With constant potential generators the roentgen-ray intensity per unit current and under defined conditions of distance, field area, and filter offers a sensitive indication of the voltage.

In the subsequent paper the effect of voltage, filtration, treatment distance, and filed area on depth dose and other characteristics of the roentgen rays produced by this generator are described.

The authors acknowledge the able assistance of Mr. Augustus T. Norton, Jr., and Mr. Francis J. Safford, and of the members of the WPA medical radiation group at the Institute. We especially acknowledge the generous grant of the Godfrey M. Hyams Trust which made possible the development described in this paper.

REFERENCES

1. Trump, J. G., and Van de Graaff, R. J. Compact pressure-insulated electrostatic x-ray generator. *Phys. Rev.*, 1939, *55*, 1160–1165.
2. Dresser, R., Trump, J., and Van de Graaff, R. J. Production of supervoltage roentgen rays by means of electrostatic generator. Am. J. Roentgenol. &. Rad. Therapy, 1937, *38*, 758–761.
3. Trump, J. G., Safford, F. J., and Van de Graaff, R. J. Generating voltmeter for pressure-insulated high-voltage sources. *Rev. Sc. Instruments*, 1940, *11*, 54–57.
4. Van Atta, L. C., and Northrup, D. L. Measurements of roentgen-ray production in the range 0.8 to 2.0 million volts. Am. J. Roentgenol. & Rad. Therapy, 1939, *41*, 633–636.

Vol. 44, No. 4

PHYSICAL CHARACTERISTICS OF SUPERVOLTAGE ROENTGEN RAYS

By J. G. TRUMP, D.Sc., *and* R. W. CLOUD, M.S.
Massachusetts Institute of Technology
CAMBRIDGE, MASSACHUSETTS

THE development of roentgen-ray generators of progressively higher voltage rating [1,2] has been due largely to recognition of the greater effectiveness with which the higher energy roentgen rays can be applied to deep-seated malignant growths. The two related physical characteristics responsible for this increased effectiveness are the greater penetration and the reduced scattering of the shorter wave lengths. To the roentgenologist, much information concerning these qualities of supervoltage radiation can be conveyed by physical measurement of the depth dose and the back-scattering, particularly when the variation of these qualities with increasing voltage is clearly indicated. This paper describes, for a range of constant voltages from 300 to 1,400 kilovolts, the influence on the 10-centimeter depth dose of filtration, field area, and treatment distance. Measurements were also made of the percentage of back-scattered radiation as a function of voltage. These data thus show the effect of higher voltages on those characteristics of radiation which permit a more advantageous geometrical placing of the dosage in the treatment of deep-seated cancer. Such matters as the greater skin tolerance and other clinically observed characteristics, which are needed to complete the picture for such very high voltage radiation, are beyond the scope of this research.

The roentgen-ray source was the 1.25-megavolt, pressure-insulated roentgen-ray generator developed by the Massachusetts Institute of Technology for the Massachusetts General Hospital and described in the preceding paper. This generator provided steady constant potentials which could be readily varied from 200 to 1,500 kv. with a well-defined focal spot and a steady roentgen-ray output in this voltage range.

METHOD OF MEASUREMENT

The ionization measurements at all voltages were made with a standard condenser type of thimble chamber. In the present state of the art,[3] such an instrument offers a convenient and reproducible indication of the ionization intensity, with the advantage of general use. While it is recognized that for the shorter wave lengths this instrument may depart somewhat from the roentgen scale because of wall effects, this departure is relatively small and its effect on the ratio of two readings, as in depth dose measurements, is probably even smaller.

All depth dose measurements were made with a 14-inch cube masonite press-wood phantom. It was found that for the higher voltages the defining lead diaphragm should be kept well back from the phantom in order to reduce the amount of forward scattered radiation which has the effect of reducing the depth dose.

EFFECT OF FILTER ON DEPTH DOSE

Figure 1 shows the effect of increasing filtration on the depth dose at 70 cm. for both 1,000 and 1,200 kv. It can be seen that the depth dose increases progressively with increasing filtration, though more rapidly at first. The addition of 2 mm. of lead to the initial filter of 0.5 mm. Au, 5 mm. Cu, and 2 mm. Al increased the depth dose by about 2 per cent which is more than half the gain effected by the addition of 8 mm. of lead. It would appear, therefore, that the additional 2 mm. of lead would produce most of the desired gain in depth dose without too great a reduction in beam intensity. As might be expected, the 1,200 kv. radiation showed a slightly greater increase of depth dose with filtration than the 1,000 kv. radiation.

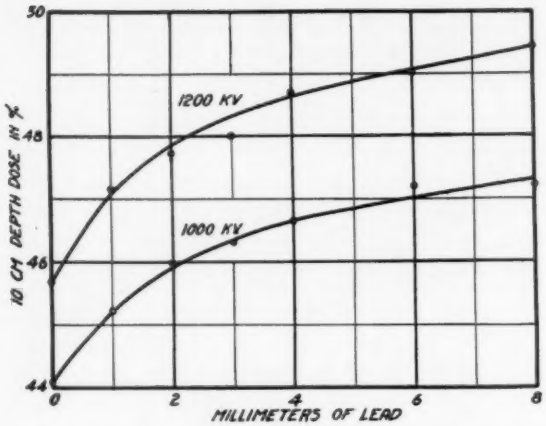


FIG. 1. Influence of filtration on the 10-cm. depth dose for 1,000 and 1,200 kv. roentgen rays. Initial filtration—0.5 mm. Au, 5 mm. Cu, 2 mm Al; field—10×10 cm.; distance—70 cm.

EFFECT OF TREATMENT DISTANCE ON DEPTH DOSE

Figure 2 shows the effect of increasing treatment distance on the 10-cm. depth dose for heavily filtered radiation produced by voltages over the range from 700 to 1,400 kv. It is seen that for 1000-kv. radiation the depth dose increases from 43.2 per cent to 45.9 per cent when the treatment distance is increased from 50 to 70 cm. A similar increase in depth dose to 48.6 per cent results from an increase in distance from 70 to 100 cm. For higher voltages a somewhat greater increase, and for lower voltages a somewhat smaller increase of depth dose with distance was obtained. Figure 3 shows the effect of treatment distance for lightly filtered radiation produced by voltages from 300 to 1,400 kv. Though the absolute value of depth dose is considerably less for the lightly filtered radiation, the effect of increasing treatment distance is about the same as before. These data show that a greater increase of depth dose with treatment distance is obtained at the higher voltages. The gain is about as great as might be deduced from a simple consideration of the inverse square law. Some departure from this law should be expected, since, for example, with a given portal the field area at the 10-cm. depth is substantially reduced as the treatment distance is increased. It appears that 70 cm. is an effective treatment distance which permits fairly high depth dose without excessive reduction of roentgen-ray intensity.

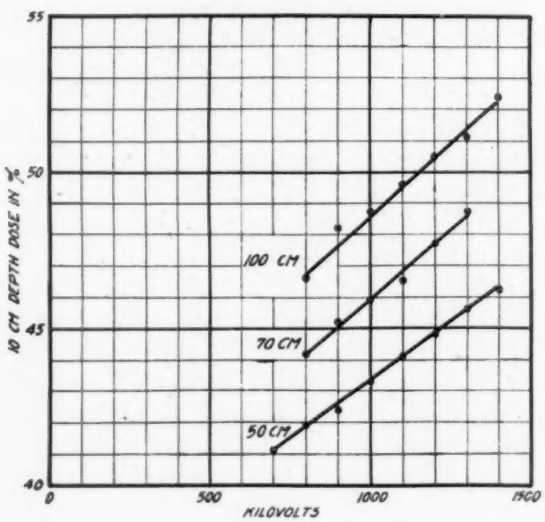


FIG. 2. Influence of treatment distance on the 10-cm. depth dose for heavily filtered roentgen rays produced by constant potentials from 700 to 1,400 kv. Filter—0.5 mm. Au, 2 mm. Pb, 5 mm. Cu, 2 mm. Al; field—10×10 cm.

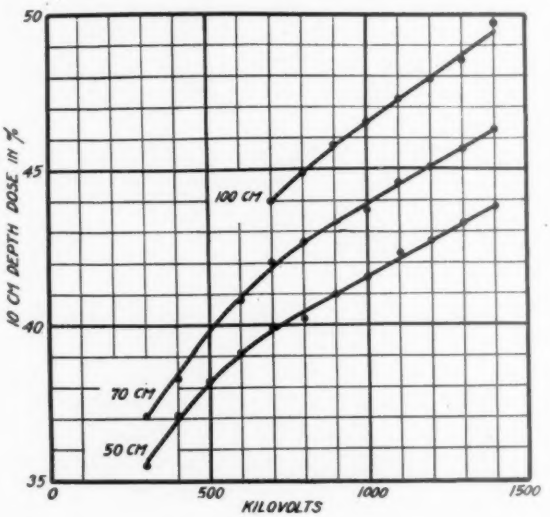


FIG. 3. Influence of treatment distance on the 10-cm. depth dose for lightly filtered roentgen rays produced by constant potentials from 300 to 1,400 kv. Filter—0.5 mm. Au, 1.25 mm. Cu; field —10×10 cm.

EFFECT OF FIELD AREA ON DEPTH DOSE

A marked increase of depth dose with increase in field area has long been recognized. Figure 4 shows the variation of 10-cm. depth dose as a function of field size for 1,000 and 1,200 kv. radiation at 70 cm., and for 200 kv. radiation with 0.5 mm. Cu filter at 50 cm. distance. The curves show that high depth doses can be obtained at high voltages even with small field areas. At the lower voltages, fairly high depth doses may be obtained by using large field areas, though such large field areas are often undesirable from other considerations. It should be expected that with radiation produced by higher voltage the influence of field area on depth dose should be less due to the relative increase in forward scattering. It can be seen from Figure 4 that the higher voltages give a striking advantage in depth dose even for the 20 by 20 cm. field with an even greater gain for the small fields. This characteristic of very high volt-

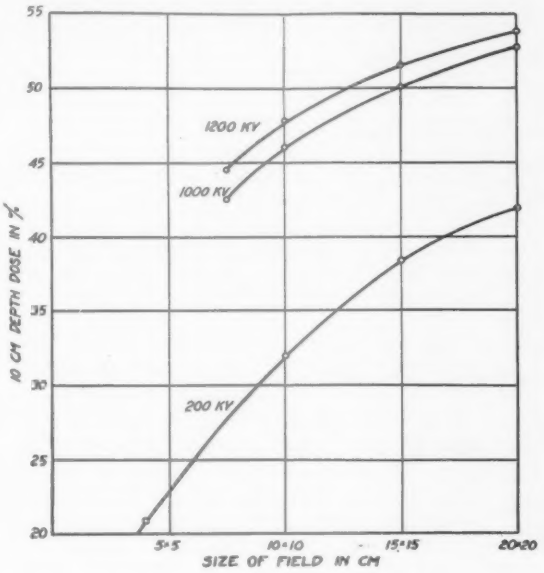


Fig. 4. Variation of the 10-cm. depth dose with field size for 200, 1,000, and 1,200 kv. roentgen rays. Distance—70 cm. for 1,000 and 1,200 kv. rays, 50 cm. for 200 kv. rays; filter—0.5 mm. Au, 2 mm. Pb, 5 mm. Cu, and 2 mm. Al for 1,000 and 1,200 kv. rays, 0.5 mm. Cu for 200 kv. rays.

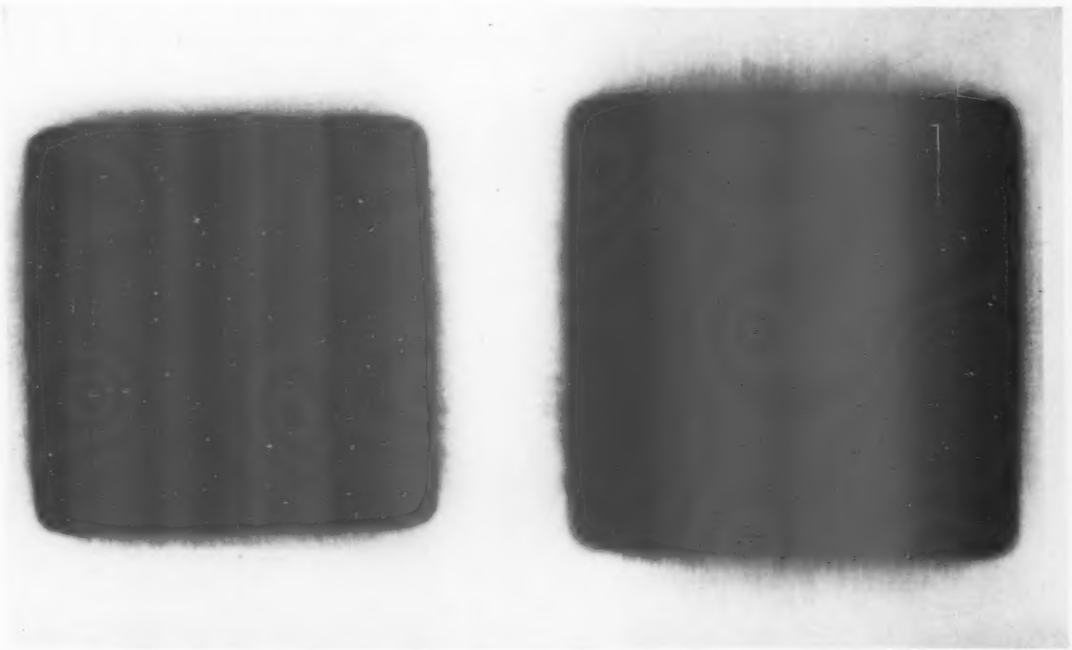


Fig. 5. Exposures produced simultaneously by a 1,000 kv. roentgen-ray beam on a film on the upper surface of the phantom (left) and on a film embedded 10 cm. below the surface (right). Size of field at the surface, 10×10 cm.

age radiation makes possible the more effective irradiation of deep-seated cancers even with small portals, and is of particular advantage in cross-firing.

BACK-SCATTERING AS A FUNCTION OF VOLTAGE

A desirable characteristic of supervoltage roentgen radiation is the marked reduction in back- and side-scattered radiation. This results in greater depth dose and reduces the radiation to which tissue adjacent to the beam, as well as skin tissue at the point of beam entry, is exposed. Measurements of the radiation scattered back from the surface indicated that back-scattering reduces steadily from about 32 per cent at 200 kv. to about 7 per cent at 1,200 kv. Side-scattering may also be expected to diminish with voltage. The reduced scattering of 1,000-volt radiation is illustrated by Figure 5. This shows at the left a film exposed on the surface of the phantom to a 10 by 10 cm. beam of 1,000 kv. radiation, and shows at the right a second film, simultaneously exposed but in this case embedded 10 cm. below the surface of the phantom. The well-defined beam area and the relative absence of exposure around this area, even for the film under 10 cm. of phantom, is qualitative evidence of the low scattering at the higher voltages.

CONCLUSION

Studies of the physical characteristics of the radiation produced in a voltage range from 300 to 1,400 kv. by a constant potential electrostatic roentgen-ray generator indicate that throughout this range an increase in voltage is accompanied by an increase in depth dose with a reduction in scattering.[4] The curves give quantitative information over a range of voltages on the effect of filtration, field area, and treatment distance on depth dose. Based on these data, filtration of 2 mm. of lead, 5 mm. of copper, and 2 mm. of aluminum, and a treatment distance of 70 cm. seems appropriate for this roentgen-ray source. Under these conditions of filtration and distance, and with a 10 by 10 cm. field, a treatment rate of 45 roentgens per minute measured by the standard thimble chamber in free air will be obtained with the generator operating at 1,200 kv. with 0.5 ma. on the target.

The authors acknowledge the assistance of Mr. Augustus T. Norton and the helpful advice of Dr. R. J. Van de Graaff. The radiation source used in this research was developed with the aid of a grant from the Godfrey M. Hyams Trust.

REFERENCES

1. Allibone, T. E., Bancroft, F. E., and Innes, G. S. St. Bartholomew's Hospital x-ray tube for one million volts. *J. Inst. Electric. Engineers*, 1939, *85*, 657–673.
2. Charlton, E. E., Westendorp, W. F., Dempster, L. E., and Hotaling, G. New million volt x-ray outfit. *J. Applied Physics*, 1939, *10*, 374–385.
3. Taylor, L. S., Singer, G., and Charlton, A. L. Measurement of supervoltage x-rays with free-air ionization chamber. Am. J. Roentgenol. & Rad. Therapy, 1939, *41*, 256–275.
4. Lauritsen, T. Depth dose measurements with 1,000 kv. roentgen tube. Am. J. Roentgenol. & Rad. Therapy, 1939, *41*, 1003–1006.

Vol. 44, No. 4

THE AMERICAN JOURNAL OF ROENTGENOLOGY AND RADIUM THERAPY

Editor: Lawrence Reynolds, M.D. *Assistant Editor:* Ruth Bigelow, B.S.

Editorial Board: A. C. Christie, M.D. E. H. Skinner, M.D. Lauriston S. Taylor
Advisory Board for Pathology: James Ewing, M.D. Eugene L. Opie, M.D.
Collaborating Editors: The Offices and Committee Members of the Societies of which this Journal is the official organ, whose names appear on this page, are considered collaborating editors of this Journal.
Foreign Collaborators: A. Béclère, M.D., Paris, Gosta Forssell, M.D., Stockholm, G. F. Haenisch, M.D., Hamburg, R. Ledoux-Lebard, M.D., Paris.

Publisher: Charles C Thomas, 220 East Monroe St., Springfield, Illinois.

Issued Monthly. Subscription $10.00 per year, $11.00 in Canada and $12.00 in foreign countries. Advertising rates submitted on application: Editorial office, 110 Professional Building, Detroit, Mich. Office of publication 220 E. Monroe St., Springfield, Ill. Information of interest to all readers will be found on page iv.

Officers and Standing Committees

THE AMERICAN ROENTGEN RAY SOCIETY

President: E. L. Jenkinson, Chicago, Ill.; *President-Elect:* M. C. Sosman, Boston, Mass.; *1st Vice-President:* C. L. Martin, Dallas, Texas; *2d Vice-President:* R. A. Arens, Chicago, Ill.; *Secretary:* C. B. Peirce, Royal Victoria Hospital, Montreal, P.Q., Canada; *Treasurer:* J. B. Edwards, 144 Woodridge Place, Leonia, N. J.; *Historian:* Percy Brown, 475 Commonwealth Ave., Boston, Mass.

Executive Council: E. L. Jenkinson, M. C. Sosman, C. L. Martin, R. A. Arens, C. B. Peirce, J. B. Edwards, Lawrence Reynolds, Robert Drane, S. W. Donaldson, U. V. Portmann, J. W. Pierson, B. R. Kirklin, R. C. Beeler, L. C. Kinney, R. S. Bromer, Chairman, 629 Pembroke Road, Bryn Mawr, Pa.

Committee on Hospital Relations: Ross Golden, New York City, Karl Kornblum, Philadelphia, Pa., J. J. Moore, U. S. Army, D. L. Palmer, Portland, Ore., I. H. Lockwood, Chairman, Kansas City, Mo.

Committee on Safety and Standards: E. C. Ernst, St. Louis, Mo., Otto Glasser, Cleveland, Ohio, R. R. Newell, San Francisco, Calif., B. P. Widmann, Philadelphia, Pa., Lauriston S. Taylor, Chairman, Washington, D. C.

Publication Committee: H. M. Weber, Rochester, Minn., E. P. Pendergrass, Philadelphia, Pa., U. V. Portmann, Chairman, Cleveland, Ohio.

Finance Committee: H. J. Walton, Baltimore, Md., H. D. Kerr, Iowa City, Iowa, Robert Drane, Chairman, Savannah, Ga.

Committee on Scientific Exhibits: V. W. Archer, University, Va., P. A. Bishop, Philadelphia, Pa., S. W. Donaldson, Chairman, 326 N. Ingalls St., Ann Arbor, Mich.

Representatives on The American Board of Radiology: B. R. Kirklin, Rochester, Minn., U. V. Portmann, Cleveland, Ohio, LeRoy Sante, St. Louis, Mo.

Member, National Research Council: Ross Golden, New York City.

Editor: Lawrence Reynolds, 110 Professional Building, Detroit, Mich.

Assistant Editor: Ruth Bigelow, 110 Professional Building, Detroit, Mich.

Editorial Board: A. C. Christie, E. H. Skinner, Lauriston S. Taylor.

Advisory Board for Pathology: James Ewing, Eugene L. Opie.

Forty-first Annual Meeting: Hotel Statler, Boston, Mass., October 1–4, 1940.

THE AMERICAN RADIUM SOCIETY

President: Frederick W. O'Brien, Boston, Mass.; *President-Elect:* Hayes E. Martin, New York City; *1st Vice-President:* LeRoy Sante, St. Louis, Mo.; *2nd Vice-President:* Leland R. Cowan, Salt Lake City, Utah; *Secretary:* William E. Costolow, 1407 S. Hope St., Los Angeles, Calif.; *Treasurer:* Charles L. Martin, 3501 Gaston Ave., Dallas, Tex.

Executive Committee: E. H. Skinner, Chairman, Kansas City, Mo., W. P. Healy, New York City, L. A. Pomeroy, Cleveland Ohio.

Program Committee: H. E. Martin, Chairman, New York City, Harry Hauser, Cleveland, Ohio, George Sharp, Santa Barbara, Calif., A. W. Oughterson, New Haven, Conn.

Publication Committee: E. H. Skinner, Chairman, Kansas City, Mo., G. T. Pack, New York City, F. H. Rodenbaugh, San Francisco, Calif.

Research and Standardization Committee: Wilhelm Stenstrom, Chairman, Minneapolis, Minn., E. P. Pendergrass, Philadelphia, Pa., Otto Glasser, Cleveland, Ohio.

Education and Publicity Committee: H. N. Cole, Chairman, Cleveland, Ohio, Abraham Strauss, Cleveland, Ohio, J. T. Murphy, Toledo, Ohio.

Advisory Committee on Roentgen-Ray and Radium Protection: Edith H. Quimby, Chairman, New York City, E. C. Ernst, St. Louis, Mo., H. J. Ullmann, Santa Barbara, Calif.

Janeway Lecture Committee: Zoe A. Johnston, Chairman, Pittsburgh, Pa.

Committee on Arrangements: L. A. Pomeroy, Chairman, Cleveland, Ohio, J. R. Driver, Cleveland, Ohio, Harry Hauser, Cleveland, Ohio.

Representatives on American Board of Radiology: Douglas Quick, New York City, R. H. Stevens, Detroit, Mich., B. P. Widmann, Philadelphia, Pa.

Twenty-sixth Annual Meeting: Cleveland, Ohio, June 2–3, 1941.

EDITORIALS

THE FUNCTION OF THE VERTEBRAL VEINS AND THEIR RÔLE IN THE SPREAD OF METASTASES

THE rôle that the lymphatic system and the regional lymph nodes play in the spread of malignant lesions has long been the subject of considerable study and investigation. It has been generally accepted that this was the primary mode of extension and that in only relatively rare instances did the blood stream itself play a part, or if it played a part, it was only of secondary importance in the vast majority of cases. However, it has often been observed that metastatic abscesses and metastatic tumors appeared in locations that did not seem to be in line of direct spread from their primary focus. No one has been in a better position to testify to this fact than the roentgenologist, and we have been at great pains to explain the ease with which a well-trained roentgenologist can make the diagnosis of carcinoma of the prostate from the peculiar type and distribution of bone lesions in the pelvis and lumbar spine, and yet up to now the mode of extension of these metastases has been inadequately explained. One would think that with all of the various investigations that were carried out in anatomical laboratories throughout the years, a venous plexus so important as the "vertebral veins" would long ago have been discovered and its proper function in the venous system explained.

It remained, however, for Batson, in a brilliant series of investigations, to discover the vertebral veins and their function and their rôle in the spread of metastases. His curiosity was stimulated in an attempt to adequately explain the typical and peculiar distribution of the metastatic lesions occurring as a result of a primary carcinoma of the prostate. He concluded that the distribution of the bone lesions was not the pattern of lymph vessel distribution and that the only anatomic system into which this pattern fits is the system of veins which, in its plexiform ramifications, infiltrates and invests the sacrum, the lumbar spine, and the adjacent wings of the ilia. He suggested several years ago that the architecture of this plexus of veins could be explored by taking advantage of the pelvic anastomoses of the deep dorsal vein of the penis and that the connections and the collateral circulations of this vein are identical with those of the prostatic plexus of veins with which it connects. He also observed that valves in the veins in this region are exceedingly variable and that all valves present permit flow toward the sacral venous plexus.

The preliminary report of this investigation was read before the Conference of Eastern Radiologists in Philadelphia in 1938. Batson has continued his investigations, and a more recent report* confirms his previous impressions and extends enormously our knowledge of a hitherto unrecognized plexus of veins and the important rôle which they play in malignant tumors.

As is so often the case in a well thought out problem of investigation, the methods of attack in elucidating the problem may be surprisingly simple, and such is true of the injection experiments carried out by Batson. In the first experiments which he performed, he used a thick radiopaque material and injected it into the dorsal vein of the penis in an adult cadaver. The course and the progress of the injection was fol-

* Batson, O. V. The function of the vertebral veins and their rôle in the spread of metastases. *Ann. Surg.*, July, 1940, *112*, 138–149.

lowed under the roentgenoscope. The mass of the injection entered the prostatic plexus of veins, passed along vessels of the lateral pelvic wall into the common iliac vein of either side and then to the vena cava inferior. The lateral sacral veins were well injected and it was found that the material passed into the bones of the pelvis and into the sacral canal. As he had thought, the injection gave a pattern which was an exact replica of the pattern made by the early spread of carcinoma of the prostate.

Other experiments were performed in a similar manner and it was found that the material injected progressed up the spine through successive anatomic regions. Many intercostal veins were filled as well as the veins of the bony pelvis. Upon increasing the amount, the injected material reached the base of the skull and entered the cranial cavity.

Repeated experience with the injection has brought out the fact that the result of the first experiments was not an accident and that the injections could be repeated on other cadavers and identical observations made.

The experiments were not confined to cadavers but animal injection experiments were made and similar results obtained. It was found in the animal experiments that the entire system of epidural and vertebral veins has a free and rich anastomosis at each spinal segment with the veins of the thoracico-abdominal cavity, and that the pressure in the system is very low. It occurred to Batson that with every compression on the trunk, such as happens many times daily in straining, in lifting, in coughing, and in holding one's breath, the intratruncal pressure would be raised to a sufficient height so that blood would flow, not into the inferior vena cava, but into this vertebral system of veins. In a series of ingenious experiments on the monkey he found that his hypothesis was correct, namely, that in compression of the chest and abdomen, with the larynx and other sphincters closed, not only is the blood prevented from entering the chest by way of veins, but blood is actually squeezed out of the intra-abdonimal veins into the vertebral vein system. He points out the significance of this in that in any condition accompanied by coughing or straining there would be a tendency to increase the flow of blood into this venous system and that this may account for the high incidence of cranial metastases in lung abscesses and in bronchogenic carcinoma. He found there was a distinct parallelism between the injections made in live animals and in those on the cadaver.

Following his brilliant experiments in determining the spread of metastases in neoplastic diseases involving the pelvic area, Batson investigated some of the "paradoxic" metastases in breast tumors. He found that after the injection of a few cubic centimeters of opaque medium into the small veins of the left breast of an adult female cadaver, the material was found in the clavicles, in the intercostal veins, in the head of the humerus, in the cervical vertebrae, in the transverse cranial venous sinus, and even in the superior longitudinal sinus. Some of the material was also found in the azygos vein and in the superior caval system. The spread of the injected material paralleled the spread of many of the so-called aberrant metastases from the breast.

As a result of his investigations, Batson has developed a concept of a vast intercommunicating system of veins which, on the ground of anatomic injections, animal experiments and simple logic, is constantly and physiologically the site of frequent reversals of flow. During these reversals a pathway up and down the spine exists which does not involve the heart or the lungs. The pathway has many connections. It provides a ready explanation for many of the aberrant metastatic patterns seen in cancer and explains the absence of lung involvement in so many of these widespread metastatic processes.

Batson refers to these veins about the vertebral column with their connections as the "vertebral veins" and he proposes, in addition to the recognized system of veins,

namely the pulmonary, the caval and the portal, that because of its anatomic structure, its physiologic and its pathologic importance, we add, as a fourth, the vertebral system of veins. These vertebral veins with their rich, valveless ramifications and connections offer a splendid solution to the difficulty which we have experienced in the past in explaining certain metastatic processes. This group of veins cannot be too well understood by the roentgenologist and the radiotherapist because of its great importance in the transport of malignant tumor cells. Undoubtedly some of the brilliant results obtained in treating the retroperitoneal lymph nodes in primary cancer of the pelvic organs under the impression that the lymphatics were being treated are due in no small part to the fact that this great plexus of veins was also being irradiated. Batson calls attention to the fact that not only does this vertebral venous system explain the metastatic manifestations observed in cancer but helps to explain in large measure the disasters which occasionally follow the diagnostic injections of perirenal air, and the occasional blindness after pneumothorax. He and his coworkers are investigating this problem.

We await with no little interest the outcome of this and other experiments which undoubtedly will add much more to our knowledge of hitherto unexplainable and not readily explained conditions.

WILLIAM A. EVANS
1876-1940

THE ranks of the pioneers of Radiology are thinning rapidly. The men who toiled with the cranky gas tube, the cumbersome glass plate and the screenless film holder are dropping by the way and the passing of each of them is an occasion for regret. Such a pioneer radiologist was Dr. William A. Evans, who died on June 9, 1940.

His very active medical career extended over nearly forty years of rapid development of the science of radiology. High in the councils of the American Roentgen Ray Society and other organizations, personally acquainted with great American and international pioneers in roentgenology, he had exceptional opportunity to observe develop-

ments in his specialty and to further it both in its scientific and practical aspects. His was a constant struggle to maintain high standards of training for those who wished to specialize in radiology and rigid qualifications for the admission to the ranks of the American Roentgen Ray Society. He was in the vanguard of the conflict to gain and maintain proper recognition of radiology among the specialties, to prevent the roentgenologic department from becoming merely a means of balancing the hospital budget at the expense of the physician. He had no small part in the fight to recognize only physicians as radiologists and to prevent over-ambitious technicians, cultists or mere quacks from foisting themselves on the public as qualified interpreters of roentgenograms.

In national as well as local fields most of Dr. Evans' work was done in the committee room or by personal contact. He left the speaker's platform to those more desirous of the limelight, and thus many of his accomplishments are destined to remain obscure except to his most intimate friends. His friends, too, alone know the personal struggles and devotion to ideals which characterized his entire life and made him the dynamic champion of progress, the determined opponent of lowered standards.

William A. Evans was born in Dover in the province of Ontario on August 24, 1876. When but a small boy his family moved to the United States and established residence in Bay City, Michigan. The death of his father brought hardship and responsibility to him at an early age. Obstacles which would have been insurmountable to most young men did not lessen his determination to acquire an education. He worked to pay his own way through preparatory schools and then through medical school and was graduated from the Medical School of the University of Michigan in 1902.

Institutional training, which followed, included residence in a psychopathic hospital where his intensive study of the inmates and his studious application to texts stood him in good stead later as an expert in cases of malingering, traumatic psychoses and various disorders of the nervous system in relation to trauma. Following his hospital residence, he engaged in the general practice of medicine and surgery in a small farming community in Michigan. During several years of this activity he acquired not only an invaluable amount of experience but also an understanding of patients and of the problems of the family doctor which is had by few of the modern specialists. It was during this period that he became interested in the new therapeutic uses of radium and he obtained a small quantity for use in his practice.

Seeking wider fields of endeavor with greater opportunity for the practice of scientific medicine, he moved to Detroit in 1910 and shortly thereafter became associated with the late Dr. Preston M. Hickey in the practice of radiology. He was appointed to the staff of Harper Hospital, beginning a career of useful service to that institution which included many years as Chief of the Department of Roentgenology, and for a number of years a member of the Executive Comittee of the Hospital. It was due in no small measure to his own efforts and those of men whose careers he inspired that Harper Hospital has attained such a high rank among American hospitals.

His interest was never limited to his own field. He was constantly seeking and recognizing talent in the medical and surgical field, and numbers of men now nationally famous, owe their inspiration, their motivating energy, and their opportunity for success to the quiet yet effective aid of William A. Evans.

In addition to carrying on a busy practice, he found time to devote to civic affairs and from 1924 until shortly before his death he served continuously as a member of the Detroit Board of Health and was President of the Board for four terms. He was a great factor in the establishment of Detroit's excellent health record and interested himself especially in the public health angle of the diagnosis and treatment of tuberculosis. Later he was active in the establish-

ment of case finding surveys in Detroit and throughout Michigan which have served as models for many other communities.

The writings of Dr. Evans included many phases of radiology. Among the earlier subjects were: Pott's disease, roentgenography of the prostate, annular shadows in the chest, lateral and oblique studies of the chest, the chest of the stillborn and of the newborn and various studies on bone disease including myeloma and non-traumatic epiphyseal separation. In later years, in association with Dr. Leucutia, his writings included many notable contributions to the field of high voltage roentgen therapy in the treatment of malignant tumors.

His restless, progressive nature led him to try new methods and to encourage scientific research. He was one of the first to recognize the possibilities of supervoltage roentgen therapy and with his associates installed one of the first machines of this type in the Department of Radiology of Harper Hospital. Employment of physicists to cooperate with practicing radiologists in solving problems of therapy and searching for new methods of diagnosing disease was his start toward his chief ambition: to establish a great institute of radiological research and practice. This ideal was kept from fulfillment by his untimely illness and death.

Dr. Evans was a highly esteemed legal expert and his services as such were in constant demand. His zeal and knowledge as well as a fine argumentative talent prevented many a miscarriage of justice and earned him the respect of the judiciary and the fearsome enmity of charlatans and shysters. His interest in establishing real facts led him to extensive study of the effects of trauma on normal and diseased tissues. He was a firm opponent of such loose and questionable terms as "traumatic arthritis," "chronic low back strain," "traumatic neurosis" and "hypertrophic arthritis," when applied to the physiologic lipping seen in the vertebrae of laboring men. It is regrettable that he did not give the world more benefit of his wisdom through publication of a volume on trauma and disease.

Another of Dr. Evans' attainments not widely known was his talent in the field of fractures. Almost uncanny ability to correct malpositions which others considered hopeless or incapable of improvement earned him a well deserved local reputation.

Dr. Evans was Treasurer of the American Roentgen Ray Society for a period of seventeen years and was elected President for the year 1932–1933. To him belongs much of the credit for the high standard of the American Journal of Roentgenology and Radium Therapy effected during his years of service on the Executive Council and the Publication Committee.

Dr. Evans was also a Fellow of the American College of Radiology, a Fellow of the American College of Physicians, a member of the Radiological Society of North America, and many others. In addition to his position as chief of the Department of Radiology at Harper Hospital, he served as consultant to Charles Godwin Jennings Hospital, Florence Crittenton Hospital, Woman's Hospital, Herman Kiefer Hospital, Detroit Tuberculosis Sanatorium and the United States Marine Hospital.

It is difficult in a brief summary to do justice to the career of such a man as Dr. Evans. While many of his contributions to his time and to posterity are well known, more were intangible and not of record. His was not a complacent nature. A man of strong principles, he defended and furthered his ideals with untiring zeal regardless of popularity or personal record.

Radiology has lost a pioneer, a sturdy champion.

Public Health has lost a tireless worker, a fearless crusader.

His associates have lost a wise counsellor, an exemplary teacher, and a staunch friend.

E. Walter Hall

JAMES WILSON HUNTER, JR.
1878-1940

DR. JAMES WILSON HUNTER, JR. was born in Norfolk, Virginia, April 30, 1878, and died at the Army and Navy General Hospital, Hot Springs, Arkansas, May 11, 1940, of coronary occlusion, having been in ill health for some time.

Dr. Hunter received his A.B. and M.A. degrees from the University of Virginia in 1899 and his M.D. from the same institution in 1901.

He early became interested in roentgenology and was one of the pioneer radiologists in his community, which specialty he followed until his retirement from active practice at the close of the past year on account of failing health. He was author

of numerous papers on radiology and in later years he became much interested in electrocardiography and wrote several papers on this subject.

Dr. Hunter was a Fellow of the American College of Physicians and the American College of Radiology, a diplomate of the American Board of Radiology, a member of the American Roentgen Ray Society, the Radiological Society of North America, the American Heart Association, the American Medical Association, the Virginia State Medical Society, Norfolk County Medical Society and the Radiological Society of Virginia. He was an Ex-President of the Norfolk County Medical Society and during the World War he was a Captain in the Medical Corps of the U. S. Army.

Friendly, affable and courteous, Dr. Hunter exemplified the principles of honor and gentility and he will be greatly missed, particularly by those who knew him.

Clayton W. Eley

SOCIETY PROCEEDINGS, CORRESPONDENCE AND NEWS ITEMS

Items for this section solicited promptly after the events to which they refer.

MEETINGS OF ROENTGEN SOCIETIES*

United States of America

American Roentgen Ray Society
Secretary, Dr. C. B. Peirce, Royal Victoria Hospital, Montreal, Canada. Annual Meeting: Cincinnati, Ohio, 1941.

American College of Radiology
Secretary, Mac F. Cahal, 540 N. Michigan Ave., Chicago, Ill. Next annual meeting: 1941, to be announced.

Section on Radiology, American Medical Association
Secretary, Dr. J. T. Murphy, 421 Michigan St., Toledo, Ohio. Annual meeting: Cleveland, Ohio, June 2-6, 1941.

Radiological Society of North America
Secretary, Dr. D. S. Childs, 607 Medical Arts Bldg., Syracuse, N. Y. Annual meeting: Cleveland, Ohio, Dec. 2–6, 1940.

Radiological Section, Baltimore Medical Society
Secretary, Dr. Walter L. Kilby, Baltimore. Meets third Tuesday each month, September to May.

Radiological Section, Connecticut Medical Society
Secretary, Dr. Max Climan, 242 Trumbull St., Hartford, Conn. Meets twice annually in May and September.

Section on Radiology, Illinois State Medical Society
Secretary, Dr. H. W. Ackemann, 321 W. State St., Rockford, Ill.

Radiological Section, Los Angeles Co. Med. Soc.
Secretary, Dr. Wilbur Bailey, 2007 Wilshire Blvd., Los Angeles, Calif. Meets on second Wednesday of each month at County Society Building.

Radiological Section, Southern Medical Association
Secretary, Dr. Roy G. Giles, Temple, Texas.

Brooklyn Roentgen Ray Society
Secretary, Dr. L. J. Taormina, 1093 Gates Ave., Brooklyn, N. Y. Meets monthly on first Tuesday, October to April.

Buffalo Radiological Society
Secretary-Treasurer, Dr. Joseph S. Gian-Francheschi, 610 Niagara St., Buffalo, N. Y. Meets second Monday of each month except during summer months, place of meeting selected by the host.

Chicago Roentgen Society
Secretary, Dr. C. J. Challenger, 3117 Logan Blvd. Meets second Thursday of each month October to April inclusive at the Palmer House.

Cincinnati Radiological Society
Secretary, Dr. J. E. McCarthy, 707 Race St., Cincinnati, Ohio. Meets third Tuesday of each month, October to May, inclusive.

Cleveland Radiological Society
Secretary, Dr. H. A. Mahrer, 10515 Carnegie Ave. Meets at 6:30 P.M. at Mid-Day Club rooms on fourth Monday each month, October to April, inclusive.

Denver Radiological Club
Secretary, Dr. P. R. Weeks, 520 Republic Bldg., Denver, Colo. Meets third Friday of each month.

Detroit Roentgen Ray and Radium Society
Secretary, Dr. E. R. Witwer, Harper Hospital. Meets monthly on first Thursday from October to May, at Wayne County Medical Society Building.

Florida State Radiological Society
Secretary, Dr. J. N. Moore, 210 Professional Bldg., Ocala, Florida. Meetings in May and November.

Georgia Radiological Society
Secretary, Dr. R. C. Pendergrass, Prather Clinic Bldg., Americus, Ga. Meets in November and at annual meeting of Medical Association of Georgia in the spring.

Illinois Radiological Society
Secretary, Dr. Wm. DeHollander, St. John's Hospital, Springfield, Ill. Meetings held quarterly, on the fourth Sunday of the month.

Indiana Roentgen Society
Secretary, Dr. C. C. Taylor, 23 E. Ohio St., Indianapolis, Ind. Meeting held the second Sunday in May annually.

Kentucky Radiological Society
Secretary, Dr. J. C. Bell, 402 Heyburn Bldg., Louisville. Meets annually in Louisville on third Sunday afternoon in April.

Long Island Radiological Society
Secretary, Dr. Marcus Wiener, 1430-48th St., Brooklyn, N. Y. Meets Kings County Med. Soc. Bldg. monthly on fourth Thursday, October to May, 8:30 P.M.

Michigan Association of Roentgenologists
Secretary, Dr. J. E. Lofstrom, 1536 David Whitney Bldg., Detroit. Three meetings a year, Fall, Winter, Spring.

Milwaukee Roentgen Ray Society
Secretary, Dr. I. I. Cowan, Mt. Sinai Hospital, Milwaukee, Wis. Meets monthly on first Friday at University Club.

Minnesota Radiological Society
Secretary, Dr. J. P. Medelman, 572 Lowry Medical Arts Bldg., St. Paul.

Nebraska Radiological Society
Secretary, Dr. D. A. Dowell, Medical Arts Bldg., Omaha, Nebr. Meets third Wednesday of each month, at 6 P.M. at either Omaha or Lincoln.

New England Roentgen Ray Society
Secretary, Dr. A. O. Hampton, Massachusetts General Hospital, Boston, Mass. Meets monthly on third Friday, Boston Medical Library.

Radiological Society of New Jersey
Secretary, Dr. W. J. Marquis, 198 Clinton Ave., Newark. Meets annually at time and place of State Medical Society. Mid-year meetings at place chosen by president.

New York Roentgen Society
Secretary, Dr. E. J. Ryan, St. Luke's Hospital, New York City. Meets monthly on third Monday, New York Academy of Medicine, at 8:00 P.M.

North Carolina Roentgen Ray Society
Secretary, Dr. Major Fleming, Rocky Mount, N. C. Annual meeting at time and place of State Medical Society. Mid-year scientific meeting at place designated.

Central New York Roentgen Ray Society
Secretary, Dr. C. F. Potter, 820 S. Crouse Ave., Syracuse. Three meetings a year. January, May, November.

Ohio Radiological Society
Secretary, Dr. J. E. McCarthy, 707 Race St., Cincinnati. Meets at time and place of annual meeting of Ohio State Medical Association.

Pacific Roentgen Society
Secretary, Dr. L. H. Garland, 450 Sutter St., San Francisco, Calif. Meets annually, during meeting of California Medical Association.

Pennsylvania Radiological Society
Secretary, Dr. L. E. Wurster, 416 Pine St., Williamsport Pa. Meets annually.

Philadelphia Roentgen Ray Society
Secretary, Dr. B. R. Young, Temple University Hospital. Meeting first Thursday of each month from October to May inclusive, at 8:15 P.M., in Thompson Hall, College of Physicians, 19 S. 22d St.

Pittsburgh Roentgen Society
Secretary, Dr. W. H. Jacox, 4800 Friendship Ave. Meetings held second Wednesday each month, 4:30 P.M., October to June at various hospitals.

Rochester Roentgen Ray Society, Rochester, N. Y.
Secretary, Dr. S. C. Davidson, 277 Alexander St. Meets on second Thursday from October to May, inclusive, 8 P.M., Rochester Academy of Medicine Building.

St. Louis Society of Radiologists
Secretary, Dr. W. K. Mueller, University Club Bldg. Meets fourth Wednesday of October, January, March and May, at a place designated by the president.

San Francisco Radiological Society
Secretary, Dr. H. A. Hill, 450 Sutter St., San Francisco. Meets monthly on third Thursday at 7:45 P.M., first six months at Toland Hall, second at Lane Hall.

* Secretaries of Societies not here listed are requested to send the necessary information to the Editor.

South Carolina X-Ray Society
Secretary, Dr. T. A. Pitts, Baptist Hospital, Columbia, S. C. Meets in Charleston on first Thursday in November, also at the time and place of South Carolina State Medical Association.

Tennessee Radiological Society
Secretary, Dr. F. B. Bogart, 311 Medical Arts Bldg Chattanooga, Tenn. Meets annually at the time and place of the Tennessee State Medical Association.

Texas Radiological Society
Secretary, Dr. L. W. Baird, Scott and White Hospital, Temple, Texas. Next annual meeting, January 18, 1941, Sherman, Texas.

University of Michigan Department of Roentgenology Staff Meeting
Meets each Monday evening from September to June, at 7 P.M. at University Hospital.

University of Wisconsin Radiological Conference
Secretary, Dr. E. A. Pohle, 1300 University Ave., Madison, Wis. Meets every Thursday from 4:00–5:00 P.M., Room 301, Service Memorial Institute.

Virginia Radiological Society
Secretary, Dr. C. H. Peterson, 603 Medical Arts Bldg., Roanoke, Va. Meets annually in October.

Washington State Radiological Society
Secretary, Dr. K. J. Holtz, American Bank Bldg., Seattle. Meets fourth Monday of each month at the College Club, Seattle.

Cuba

Sociedad Cubana de Radiologica y Fisioterapia
Secretary, Dr. Francisco Padron, Enrique, Villuendas 64, Havana, Cuba. Meets monthly in Havana.

British Empire

British Institute of Radiology Incorporated with the Röntgen Society
Meets monthly on third Thursday from November to June inclusive, at 8:15 P.M., 32 Welbeck St., London.

Section of Radiology of the Royal Society of Medicine (Confined to Medical Members)
Meets on the third Friday of each month during the winter at 8:15 P.M. at the Royal Society of Medicine, 1, Wimpole St., London, W. 1.

Faculty of Radiologists
Secretary, Dr. M. H. Jupe, 32 Welbeck St., London, W. 1, England.

Section of Radiology and Medical Electricity, Australasian Medical Congress
Secretary, Dr. H. M. Cutler, 139 Macquarie St., Sydney, New South Wales.

Radiological Section of the Victorian Branch of the British Medical Association
Secretary, Dr. Keith Hallam, St. George's Hospital, K.E.W., Melbourne, E. 4, Victoria, Australia. Meets monthly from March to November inclusive for scientific discussion.

Canadian Association of Radiologists
Secretary, Dr. A. C. Singleton, Medical Arts Bldg., Toronto, 5, Ontario.

Section of Radiology, Canadian Medical Association
Secretary, Dr. C. M. Jones, Inglis St., Ext., Halifax, N. S.

Radiological Section, New Zealand British Medical Association
Secretary, Dr. Colin Anderson, Invercargill, New Zealand. Meets annually.

Continental Europe

Belgian Society of Roentgenology
Secretary, Dr. J. Boine, Avenue des Alliés, 134 ,Louvain (Belgium). Meets monthly on second Sunday at d'Egmonds Palace, Brussels, except in the summertime.

Sociedad Espanola de Radiologia y Electrologia
Secretary, Dr. J. Martin-Crespo, Fuencarral, 7. Madrid, Spain. Meets monthly in Madrid.

Société de Radiologie Médicale de France
Meets monthly on second Tuesday, except during months of August and September, 12 Rue de Seine, Paris.

Société Suisse de Radiologie (Schweizerische Röntgen-Gesellschaft)
Secretary for French language, Dr. A. Grosjean La Chaux de Fonds.
Secretary for German language, Dr. Scheurer, Molzgasse, Biel. Meets annually in different cities.

Société Francaise d'Electrothérapie et de Radiologie Médicale
Meets monthly on fourth Tuesday, except during months of August and September, 12 Rue de Seine, Paris.

Association of German Roentgenologists and Radiologists in Czecho-Slovakia
Secretary, Dr. Walter Altschul, German University, Prague, 11.52.

Deutsche Röntgen-Gesellschaft (Gesellschaft für Röntgenkunde und Strahlenforschung)
Meets annually in April, alternating one year in Berlin, one year in some other German city. Meets in addition every two years with the Gesellschaft deutscher Naturforscher und Aertze.
Permanent Secretary, Professor Dr. Haenisch, Klopstockstrasse 10, Hamburg, Germany.

Süd- und Westdeutsche Röntgengesellschaft
Meets annually in different cities.

Nord- und Ostdeutsche Röntgengesellschaft
Meets annually in different cities.

Dutch Society of Electrology and Roentgenology
Holds two meetings a year in Amsterdam, one in the spring, and one in the fall.

Societa Italiana Radiologia Medica
Secretary, M. Ponzio, University of Turin, Prof. Turin.

Societatea Romana de Radiologie si Electrologie
Secretary, Dr. Oscar Meller, Str. Banul Măräcine, 30, S. I., Bucuresti, Roumania. Meets second Monday in every month with the exception of July and August.

All-Russian Roentgen Ray Association, Leningrad, USSR in the State Institute of Roentgenology and Radiology, 6 Roentgen St.
Secretaries, Drs. S. A. Reinberg and S. G. Simonson. Meets annually.

Leningrad Roentgen Ray Society
Secretaries, Drs. S. G. Simonson and G. A. Gusterin. Meets monthly, first Monday at 8 o'clock State Institute of Roentgenology and Radiology, Leningrad.

Moscow Roentgen Ray Society
Secretaries, Drs. L. L. Holst, A. W. Ssamygin and S. T. Konobejevsky. Meets monthly on first Monday at 8 o'clock.

Polish Society of Radiology
Secretary, Dr. Jan Kochanowski, 45 Gornoslazka St., Warsaw. Meets annually.

Warsaw Section, Polish Society of Radiology
Secretary, Dr. B. Krynski, 11 Zielna St. Meets once a month except in the summertime.

Scandinavian Roentgen Societies
The Scandinavian roentgen societies have formed a joint association called the Northern Association for Medical Radiology, meeting every second year in the different countries belonging to the Association. Each of the following societies, with exception of the Denmark Society, meets every second month except in the summertime.

Society of Medical Radiology in Sweden
Meets in Stockholm.

Society of Medical Radiology in Norway
Meets in Oslo.

Society of Medical Radiology in Denmark
Secretary, Dr. G. Biering, Copenhagen. Meets the second Wednesday of each month from October to July in Copenhagen, at 8'oclock in the State Institute of Roentgenology.

Society of Medical Radiology in Finland
Meets in Helsingfors.

Vienna Roentgen Society
Meets first Wednesday of each month, at 6:30 P.M. at Zentral-Röntgen Institut des allgemeinen Krankenhauses Alserstrasse 4.

Orient

Japan X-Ray Association
c/o Orthopedic Surgery, Tokyo Imperial University. Meets annually in April.

Kinki Roentgen-Abend Society
Director, Dr. Prof. Taiga Saito, Ogawaoike Tyoto Japan. Meets bi-monthly on third Sunday.

BULLETIN OF THE INTER-SOCIETY COMMITTEE FOR RADIOLOGY*

The American College of Radiology today is functioning as most colleges. In other words, it is representing organized radiology in all its public relations, economic, and general problems that face the radiologist.

The presidential addresses for the past several years have dealt largely with the many unfair tactics used by numerous hospitals and medical groups in connection with radiological problems. This has been entirely correct; much has been accomplished and much still has to be accomplished along this line.

Thomas Hughes said, "There are two kinds of discontent in this world; the discontent that works and the discontent that wrings its hands. The first gets what it wants and the second loses what it has." We shall ever be indebted to the men who have, in addition to their scientific attainments, been unwilling to wring their hands but have spared neither time, effort, nor money in bringing radiology to its present position in medicine.

A letter of welcome to the large number of new members who came into the American College of Radiology this year brought many interesting replies. They were mainly of three types: The majority wish to cooperate and help the College in any way possible to accomplish its undertakings; others mentioned specific instances of bad ethics on the part of a hospital or radiologist and wished to know what, if anything, the College could do about it; still others cited instances in their own cities where a radiologist of national reputation was doing things which were not in the best interests of radiology, the medical profession, or the hospital and though the College was aware of these facts, it was unable to do anything about it.

My remarks this evening will be limited largely to a discussion of these letters and of the obligations of a radiologist to the public, the medical profession, the hospital, and radiology as a specialty. Later I would like to make a few suggestions as to the manner in which I believe we can help the College to more thoroughly accomplish its objects in view. I realize fully that a few radiologists in this country who have never encountered any trouble with their hospital feel that good scientific work is all that is necessary for radiology to continue to succeed. But most of us, even though we have had no trouble, are convinced that we must be well organized and work together if radiology is to be spared the fate of pathology. Theodore Roosevelt said, "Every man owes a part of his time and money to the profession in which he is engaged."

The first group of letters from individuals who offered to cooperate in every possible way needs no further discussion than the thanks and the appreciation of the College.

The communications in group two gave instances of bad ethics on the part of a hospital or radiologist and wish to know what, if anything, the College can do about it. The College has in many instances been able to materially help such situations. In other instances there have been many reasons why the College could accomplish little. In the first place bad feelings among radiologists in a city prevent their cooperation in dealing with any hospital trouble.

The third group of letters cited instances in their own cities where prominent radiologists connected with large institutions gave very little service to the hospital. This is again a difficult thing for the College to handle. Examples are cited concerning prominent men who head the departments of radiology in large institutions and who give very little of their time to these institutions. They will visit the department two or three times a week and read a few films. Interns do the fluoroscopy. Between their visits the interns and members of the staff interpret the films. This type of practice is unfair to the public, to the profession as a whole, and to radiology. In such occasions it is, however, more the duty of the radiologists in the city or cities

* President's Address by Fred M. Hodges, M.D., before the American College of Radiology, New York City, June 12, 1940.

in question to try to cope with such a state of affairs than it is for the College to attempt a solution of the problem. No radiologist should have a connection of this type with any hospital and I believe in time all fair men will discontinue such phlegmatic service. Certainly men in other specialties are not going to respect a radiological department operated in this manner. It also breeds lack of respect for radiology among interns. In a city where this type of work is done, it will almost invariably be found that radiology is not looked upon by the profession as being on a par with or equal to the other specialties. In such cities rarely does one find a radiologist in an official capacity in his local medical society. In other words, rarely is he respected as a real consultant. If one or more men give very poor service to their hospital, it also reflects discredit among their colleagues in radiology in their communities. If they should have any trouble with a hospital, the profession as a whole will not stand behind them or back them in their fight with some grasping hospital board or medical group. Cooperation among radiologists in any city is absolutely essential if radiology is to rate as high as any of the other specialties in medicine. Where good radiology is done and where the radiologists cooperate with each other and are deeply interested in helping the clinician in every case referred to him, this specialty stands just as well as any other in medicine.

I would like to strongly condemn the habit of some radiologists in remaining in their private offices and sending technicians to the hospitals for roentgen examination of patients. In this way the importance of the technical side is exaggerated by the staff and the interpretation of the films minimized. He also does not come in personal contact with the clinician or the patient and does not make friends of them.

If an established radiologist has more hospital work than he can attend to in a thorough manner, he should have well trained associates who can help him give proper service to these hospitals. He cannot be too grasping and fail to bring discredit upon his specialty.

If he is giving good service to the hospital and has made friends of the staff members, he is more apt to be able to prevent the inclusion of radiology in the various plans for hospitalization. We should, I believe, be unalterably opposed to radiology being included in hospital plans unless the other specialties are also included. Various forms of low cost medical service to low income groups are already operating satisfactorily in several states. Some physicians are opposed to this medical service but those who have had more experience with it feel that it is a good thing and that the radiologist should do his share in helping complete such plans in various parts of the country.

Two months ago I was in the office of one of America's leading radiologists and asked him what would be his subject if he had to make this talk. His immediate reply was, "If radiology is to succeed, radiologists must be consultants." He also added, "They must not only be interested in radiology itself, but must be thoroughly interested in trying to give the best possible service to the public, the medical profession as a whole, the hospital, and to radiology. He must willingly absorb the cost of a good deal of charity work and must feel that it is up to him to give the referring physician as much help as he possibly can."

More than 90 per cent of radiologists must deal with a large preponderance of general practitioners. The referring physician wants a diagnosis and in many instances suggestions as to treatment. Many men in our field have hundreds of doctors who send in a patient with a note which reads something like this: "This patient has a lesion on the face, tongue, etc. Please treat it as you think you should. If you do not think that it is a case for you to handle, please call me and advise me as to what treatment you think is indicated." A radiologist who has this type of confidence of the profession as a whole will always succeed. He naturally must be extremely careful not to abuse this confidence.

The reason that pathology has suffered so much at the hands of hospitals and medical groups is due largely to the fact that the pathologist has little personal contact with the patient. It is, of course, realized that in very large clinics it is impossible for the radiologist to see many patients personally. He has, however, daily consultations with members of the staff and in this way is familiarized with the patient as a whole and not with just one organ or part of the body. In smaller institutions and in private practice, the radiologist in charge of the department or one of his associates should see every patient, and should not only try in every possible way to help the clinician who referred the case, but to make a friend of the patient. All too frequently the patient has no idea of the name of the radiologist or anything else concerning him. Many, many times I have asked the question, "Who x-rayed you?" The answer in many cases has been, "I do not know. Dr. — sent me for the examination." In a certain percentage of cases they not only know by whom they have been x-rayed but a good deal about the radiologist who did the work. I am probably old fashioned, but I believe that a radiologist should have patients of his own, particularly in therapy. Such men as Groover felt that if radiology was to remain on a par with other specialties, the radiologist must refer patients as well as have patients referred to him. There is no reason why this should not be true in many dermatological conditions, in cancer, particularly skin cancer, etc.

Today nearly all specialists start the study of their chosen field after one or two years of hospital internship. They work from about 9:00 A.M. to 5:00 P.M. and feel that the day is over. They have several years of this without much night or Sunday work. It is true that many of the younger men in the various specialties can operate, read films, etc., as well as older men but some of these do not wish to be disturbed after 5:00 P.M., nights, or Sundays, and have no real conception of service to the public, the medical profession, or to their own specialty. They have never done general practice where the phone may ring any hour of the day or night and service must be cheerfully rendered if they can possibly hope to build a practice or make a living for themselves.

Radiologists must attend staff meetings and be sincerely interested in trying to understand and help other physicians with their troubles if they are to expect their specialty to stand on a par with the others. The American College of Radiology has, I am firmly convinced, helped the general standing of radiologists throughout the country and is helping them in their hospital relationships.

Just what can we do to help the College and the radiological societies in advancing the position of radiology?

First, we can work together in a spirit of cooperation. If a radiologist is giving good service to a hospital or medical group, he should be able to feel that other reputable radiologists are not going to undermine or underbid him in his work. For example: In one city a radiologist resigned from a hospital on account of the fact that he was only being paid about $200 a month for an enormous amount of work. The other radiologists in this city immediately met and decided that none of them would consider the appointment to this hospital. The final outcome was that the radiologist's salary was raised sufficiently for him to continue the work. His success would not have been possible except for the cooperation of all of the radiologists in his community. Some will say this is using union tactics. It isn't at all. No other branch of medicine would even consider allowing itself to be so commercialized or exploited. On the other hand, in another city a radiologist is giving extremely poor service to one of the hospitals. The other men in this community feel that his actions are lowering the standard of radiology and want the College to do something about it. They are, however, unwilling to come out in the open against this man. Naturally

the College can do nothing under such circumstances.

There is no question whatever that in the large majority of instances in all of our dealings with hospitals and the profession, education, service, and moral suasion are far better than any method which smacks of force or union tactics. Samuel Gompers said, "One fact stands out in bold relief in the history of men's attempts for betterment. That is when compulsion is used, only resentment is aroused, and the end is not gained. Only through moral suasion and appeal to men's reason can a movement succeed." This does not mean, however, that in certain instances we should not, when driven to it, fight for what is right and proper.

Often the radiologist is not giving service to the hospital and complains bitterly because some younger man who will give service is offered his position. At times hospital boards are absolutely unreasonable. A radiologist, though giving excellent service, may have trouble. Other doctors have their troubles. We must expect ours. Carlyle said, "No man lives without jostling and being jostled; in all ways he has to elbow himself through the world, giving and receiving offence."

Another thing that we can do to help the College in advancing its objectives is for all of us to try to interest men of high type to enter this field. We cannot expect a radiologist of small calibre to compete with surgeons, internists, and others of much higher type. It is true that at the present time not enough men are being trained in this field to fully take care of the specialty. Every town of 10,000 persons with a good surrounding country could well support a good radiologist. It seems to be true that a good many men are going to have to be partially trained in smaller cities throughout the country and complete their courses in special work in some of the larger centers. Unless some arrangement of this kind is made, we are obliged to expect poor radiology in many parts of America.

Since radiologists at one time considered their offices laboratories, they have in many instances failed to do all that they could for their specialty and by remaining more or less secluded have, though doing excellent work, been more or less unknown to the profession as a whole and to the laymen in their own communities. The radiologist should take an active part in his local medical society and in the national medical societies.

Through papers published and through our excellent radiological journals, our specialty is undoubtedly advancing in the scientific world and radiologists are now more generally known by the profession than has been the case in the past. As much as Dr. Pancoast did for radiology, a few years ago a professor of surgery in one of the largest universities in the East, and not a great distance from Philadelphia, on hearing Dr. Pancoast's name mentioned, asked, "Who is Dr. Pancoast?"

In the future, I believe that in the larger cities radiologists should, where possible, form groups where special study can be given to the different fields of radiology. This enables the group to have better equipment and to be more familiar with all of the different branches of radiology than is possible in smaller offices. It lowers the overhead and such a group is able to turn out better work and can more easily compete with the clinician who attempts to do his own radiology. I believe that we are obliged to have more or less specialists within the specialty if the best possible type of work is to be turned out. The large majority of unusually successful men in all branches of medicine have been particularly interested in some one phase of their specialty and have become more proficient in this more or less specialty within a specialty.

One of the things that would be an experiment but that the College could probably do to help radiologists throughout the country would be to form a department for handling a number of transparencies and case histories in some of the highly specialized fields, these to be available to any

radiologist who desires them and is willing to pay for them. For instance, a number of transparencies with case histories and final diagnoses in cranial conditions by Dyke; a similar series on the small intestine by Golden; kymography and planigraphy by Moore and Scott, would be a tremendous help to radiologists throughout the country.

I would recommend that the college take steps to determine the number of its membership which would desire this service and attempt some approximation of the expense which would be incurred.

Most of the work in the College has been done by a few public spirited men who have given a great deal of time and effort to the College. All of us are very much indebted to the entire board of chancellors for the work done during 1939 and 1940. Special thanks are due Dr. W. E. Chamberlain, Chairman of the Board; to Dr. Ross Golden, Chairman of the Committee on Constitution and By-laws; and to our Executive Secretary, Mr. Cahal.

The road to success in radiology is not a simple one but I predict a great future for this specialty if we can follow Mark Twain's advice, "Let us endeavor so to live that when we come to die even the undertaker will be sorry."

INTESTINAL OBSTRUCTION DUE TO GALLSTONE

To the Editor:

May I direct attention to the article by Dr. James M. Flynn entitled "Intestinal Obstruction at Terminal Ileum Caused by Large Irregular Gallstone" which appeared in this JOURNAL.* Dr. Flynn reports a case in which intestinal obstruction was diagnosed and later confirmed, the obstruction being due to a gallstone. He emphasizes the fact that the gallstone itself, because of its non-opaque character, was not visible in the roentgenogram so that the exact diagnosis of gallstone obstruction was not made.

A critical examination of the illustration (Fig. 1) indicates, however, that there is gas in the right upper quadrant outside the usual position of intestinal loops. Since seeing this, Dr. Flynn has been kind enough to submit the original film to me for examination; this shows clear evidence of gas in the biliary tract. In a paper entitled "Spontaneous Internal Biliary Fistula and Gallstone Obstruction" by Chauncey N. Borman and myself which was published in 1937,† we called attention to the importance of this sign in the exact diagnosis of this condition. The clinical diagnosis of gallstone obstruction is rarely made; even the diagnosis of intestinal obstruction alone is difficult, most often it is markedly delayed. We made note of the fact that a careful examination of the preliminary film of the abdomen, particularly in the right upper quadrant, might occasionally reveal the presence of gas in the biliary ducts or in the gallbladder. Such a finding added to other evidences of intestinal obstruction would lead almost inevitably to the conclusion that the obstruction was due to a recently passed gallstone producing an internal biliary fistula. This point is confirmed by the case reported by Dr. Flynn. I feel it is important to again direct attention to this diagnostic sign because its utilization should permit a more exact diagnosis, hence better therapy, in such cases.

LEO G. RIGLER

* July, 1940, *44*, 69–70.

† *Surgery*, 1937, *1*, 349–378.

BOOK REVIEWS

Books sent for review are acknowledged under: Books Received. This must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers as space permits.

Radiologie clinique du coeur et des gros vaisseaux. Par Ch. Laubry, P. Cottenot, D. Routier and R. Heim de Balsac. Tome I et II. Cloth. Price, 400 fr. per set. Pp. 339, with 1,049 illustrations. Paris: Masson et Cie, 1939.

This is a two volume publication which covers the subject of cardiac roentgenology very thoroughly. It is divided into three parts. The first is devoted to a general consideration of cardiac roentgenology with descriptions of techniques and methods of examination and investigation. In the second part, the normal heart is described and, in the third section, pathological conditions are discussed in detail. Children and infants are included in the cases presented. The final chapter deals with the diseases such as mediastinal neoplasms, thyroid tumors, mediastinal adenopathies and others which are encountered in the differential diagnosis of cardiac diseases.

Approximately 335 cases, drawn from the authors' clinical material of the past ten years, were selected for presentation and form the basis for more than 1,000 illustrations in the two volumes. The latter include reproductions of roentgenograms, pathological specimens, and line drawings. In many instances, the line drawing, in small scale, is placed in a corner of the roentgenograms resulting in ready comparison of the two. Many of the roentgenograms show the postmortem heart and vascular system injected with an opaque medium in both normal and pathological cases. Concise case histories accompany the illustrations. The various parts of cardiac anatomy are indicated by arrows.

The authors in their preface state that they have attempted the most graphic presentation possible of their subject, and they have accomplished their object. The atlas is most comprehensive and no criticism can be made for omission of any one special phase of cardiac disease. There are, too, postmortem examinations, sufficient to avoid the criticism that the study is based only on clinical observation with a lack of postmortem verification. The cardiologist may regret the inclusion of so few electrocardiograms. As a reference book for the roentgenologist it is invaluable.

R. S. Bromer

Gastrointestinal Dysfunction. By Barton Arthur Rhinehart, A.B. (Zoology), Cum Laude (Indiana) A.O.A., Associate Professor of Roentgenology, University of Arkansas School of Medicine; Consulting Roentgenologist to St. Vincent's infirmary, Arkansas Baptist Hospital, and Arkansas Children's Hospital, etc. Cloth. Price, $6.00. Pp. 311, with 48 plates. Little Rock, Arkansas: Central Printing Co., 1939.

Dr. Rhinehart dedicates his book to the proposition that nutritional deficiencies cause the majority of gastrointestinal disorders of civilization and to Sir Robert McCarrison who has done much to promulgate the above thesis. After an introductory chapter, which emphasizes the prevalence of gastrointestinal dysfunction on the basis of deficiency states rather than actual organic disease, he includes chapters on the incidence and causes of gastrointestinal dysfunction, complaints and the symptoms of the patient, as well as chapters on the anatomy and physiology of the gastrointestinal tract, with some overlapping and repetition. A short chapter is devoted to treatment. Case reports follow together with several plates of roentgenograms of the gastrointestinal tract, illustrating various normal and abnormal states.

Dr. Rhinehart is playing the rôle of a missionary in making the reader conscious of the importance of deficiency disease. He feels that this field of medicine has been grossly neglected in the past years and cannot be too strongly emphasized. He decides that the major portion of all gastrointestinal disease is on the basis of dysfunction due to deficiency and sets out to prove it by a review of the literature and some observations of his own. Dr. Rhinehart deserves credit for his zeal in trying to put over an idea as important as this to all of the medical profession and particularly to the radiologist who encounters these deficiency states in his gastrointestinal studies but heretofore has paid little attention to them.

The book is somewhat repetitious and perhaps could be better organized than has been done. This, however, is not too serious a criticism. After extracting the meat from the text, the reader should be stimulated to a better appreciation and further study of deficiency states.

Paul C. Swenson

The Hospital Care of Neurosurgical Patients. By Wallace B. Hamby, M.D., F.A.C.S., Associate Professor of Neurology and Instructor in Surgery (Neurological Surgery), University of Buffalo School of Medicine, Buffalo. Cloth. Price, $2.00. Pp. 118. Springfield, Illinois: Charles C Thomas, 1940.

At first glance, the reviewer is struck by the fact that this compact small volume appears to contradict itself in its aims. While the simplification of the parts giving anatomy and structure indicate that the book is primarily for the nurse in training, the detailed descriptions of operations in other sections fit it for a quite different purpose. The author in his introduction mentions that "this book is written for nurses and for the young physician who for the first time meets in the hospital, patients suffering from lesions that bring them under the care of the neurosurgeon." The author has been wise in seeing the need of such a book and has produced an excellent assemblage of knowledge of great practical use.

An outstanding chapter deals with the physical aids in the diagnosis of diseases of central nervous system. Unfortunately, on page 26, the author discusses the use of cisterna puncture without mentioning its dangers. The neurologists, however, are aware that in numerous conditions the brain stem is displaced and that cisterna puncture risks a dangerous or vital needling of the medulla. Perhaps more should have been put down regarding proper roentgenography in connection with lipiodol injections and certain other technical procedures. In this connection, one misses any reference to air myelography.

Throughout the book, postoperative treatment is very well stressed along with a consideration of possible postoperative complications. The clearness and orderliness in these matters is to be commended. The reviewer predicts that many young hospital residents will particularly value the sections dealing with postoperative dressings and also the inclusion of such a detail as how best to arrange the strapping in of an indwelling catheter.

It is well to note that a good index has been carefully attended to.

Thomas K. Davis

A Topographic Atlas for X-Ray Therapy. By Ira I. Kaplan, B.S., M.D., Director, Radiation Therapy Department, Bellevue Hospital; Director, Division of Cancer, Department of Hospitals, City of New York; Clinical Professor of Surgery, New York University Medical College, etc., and Sidney Rubenfeld, B.S., M.D., Associate Visiting Radiation Therapist, Bellevue Hospital; Instructor in Surgery, New York University Medical College, etc. Cloth. Price, $4.00. Pp. 120, with 55 illustrations. Chicago: The Year Book Publishers, Inc., 1939.

In this collection of 55 plates, reproducing schematic drawings by Miss Evelyn Madsen, the authors have attempted to supply the radiation therapist with graphic descriptions of topographic anatomy for every-day use in mapping treatment portals. Each plate is accompanied by brief comments regarding pertinent anatomical relations and suggestions regarding the location of treatment portals and the radiation angle best suited to the irradiation of various organs and fields.

This atlas does not supplant the more elaborate standard textbooks of topographical anatomy, nor does it illustrate relationships neglected in such books. It merely presents in compact form useful landmarks related to the sites where roentgen irradiation is commonly employed. Attractively bound in cloth, this book has been printed upon fine glazed stock necessitating a retail price which may be expected to limit its distribution somewhat.

Fred J. Hodges

Traité d'électro-radiothérapie. Tome I et II. L. Delherm et A. Laquerrière, Editors. Secrétaire Général, H. Morel Kahn; Secrétaire adjoint, H. Fischgold. Cloth. Price, 480 fr. per set. Pp. 2,018, with 450 illustrations. Paris: Masson et Cie, 1938.

Few scientific or medical treatises can truthfully be said to represent any one country. They usually represent the ideas and methods of a single individual or of a selected group of outstanding workers in a given field of science or in a given medical specialty. This rather extensive treatise in two large volumes consti-

tutes a noteworthy exception. From the multiplicity of French contributors and from the almost exclusive reference to French sources it would be difficult to conceive how any treatise could more nearly represent the French school than this one.

In one outstanding particular this work differs from all others published in this or in most other countries, and this difference will be expecially noticeable to Americans. In this country radiology, in the common use of the term, refers only to the medical uses of roentgen rays and of radium. Strictly speaking, radiology should mean all the medical uses of radiant energy including ultraviolet and infra-red rays. But, for historical reasons, ultraviolet and infra-red rays have been grouped with physical therapy, which includes the therapeutic uses of heat and cold, of massage and exercise, and of electrotherapy. In France, on the contrary, radiology as we understand it, electrology, and physical therapy have always been grouped together in one specialty known by the combined term "radiology and electrology," and state diplomas and university professorships have always included both branches. This serves to explain why this treatise deals, not only with the therapeutic uses of roentgen rays and radium, but also those of electricity, heat, cold, massage, ultraviolet rays, infra-red rays, etc.

These two volumes are well printed and bound. Each subject is discussed by contributors who have had special experience. Under each disease is given first a brief description of the condition, then a clinical summary, and finally its treatment by various physical methods or combination of these methods. As a reference work on the treatment of disease by physical agents and methods, it could not easily be improved upon.

Arthur U. Desjardins

Das Wesen und der Wert der Tomographie. (Praktische Tuberkulose-Bücherei, Heft 23.) Von Dr. W. Deutschmann, Aus den Heilstätten Beelitz der L. V. A. Berlin, Ärztlicher Direktor: Dr. Kremer. Paper. Price, RM. 3. Pp. 40, with 39 illustrations. Leipzig: Georg Thieme, 1939.

In this small volume the author presents a very condensed discussion of tomography. He describes the original investigations of M. Bocage, whom he credits with the recognition of the fundamental principles on which present day tomography is based. The value of this method of examination is illustrated in 33 roentgenograms which are briefly analyzed in the text.

Ernst A. Pohle

DEPARTMENT OF TECHNIQUE

Department Editor: Robert B. Taft, M.D., B.S., M.A., 105 Rutledge Ave., Charleston, S. C.

A SIMPLE METHOD OF ADAPTING CONVENTIONAL ROENTGENOLOGIC EQUIPMENT TO BODY SECTION ROENTGENOGRAPHY (PLANIGRAPHY)*

By W. EDWARD CHAMBERLAIN, M.D.,
and
BARTON R. YOUNG, M.D.
PHILADELPHIA, PENNSYLVANIA

For the past year we have carried out body section roentgenographic studies utilizing apparatus that is ordinarily available for conventional roentgen examinations but is easily converted into a planigraph by the attachment of several home-made parts. These attachments were made in our roentgen department machine shop at relatively little cost so that expenditure for planigraphic equipment has been negligible.

The apparatus allows simultaneous longitudinal movements of the roentgen tube and film in opposite directions in a straight line. This is accomplished by attaching one end of a tubular shaft to the horizontal arm that supports the roentgen tube while the remainder of the shaft is free to slide through two ball-bearing guides (Fig. 1*A*). One of these trombone-action guides is attached to the Potter-Bucky diaphragm tray so that its swivel axis is accurately

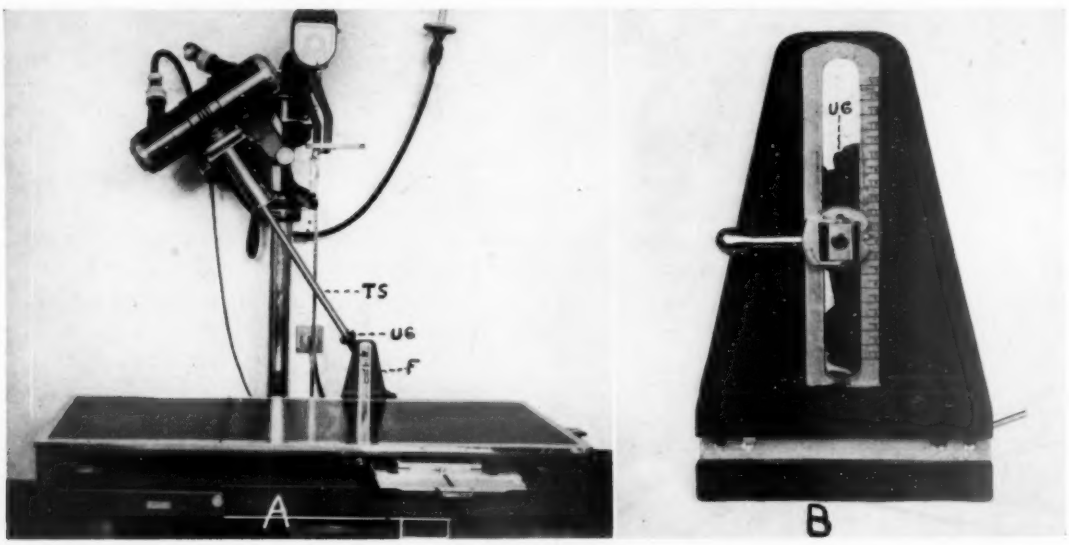


Fig. 1. *A*, photograph of home-made planigraphic apparatus showing roentgen tube and film at end of excursion. During longitudinal roentgen tube-film travel, tubular shaft, *TS*, slides through two trombone-action guides. The upper guide, *UG*, is adjustable to the focal plane level at the fulcrum guide, *F*, while the lower guide, *LG* (shown in Fig. 2) is attached to the Potter-Bucky diaphragm tray at level of plane of film. *B*, close-up of fulcrum guide showing scale in centimeters. Upper trombone-action guide, *UG*, is raised or lowered to desired distance above table top (focal plane of body) and then fixed at this level to fulcrum guide by tightening lock nut.

* From the Department of Radiology, Temple University Medical School, Philadelphia, Pa.

situated in the plane of the film, thus insuring that body section plane is at level indicated by fulcrum (Fig. 2). Film travel is activated through this guide. The swivel axis of the other trombone-action guide is adjustable to the desired focal plane level of the patient by raising or lowering it at the fulcrum guide (Fig. 1*B*).

The tube and film move in horizontal planes which are therefore parallel to each other and to the plane of the body under examination. The longitudinal motion of the tube is approximately equal to the target film distance and the tube tilts during its travel so that the central ray is always directed at the center of the film. The focal spot of the tube is situated in its axis of tilt because if the focal spot is above or below this axis, blurring will occur in the planigraphic image.

The construction of the above-described apparatus is such that it satisfies the minimum requirements for planigraphy. The use of this equipment makes available body section roentgenography when the acquisition of more elaborate apparatus is impossible. Various methods of producing the planigraphic motion are available. The simplest is the so-called "manual" method in which a nurse or other assistant pushes the tube-stand from one end of its traverse to the other. All other methods add to the expense but are desirable because they make it unnecessary for an assistant to be exposed to scattered roentgen rays during the procedure. The technical results are the same. We recently installed a motor driven device and find that the film records are no different from those obtained by the manual method.

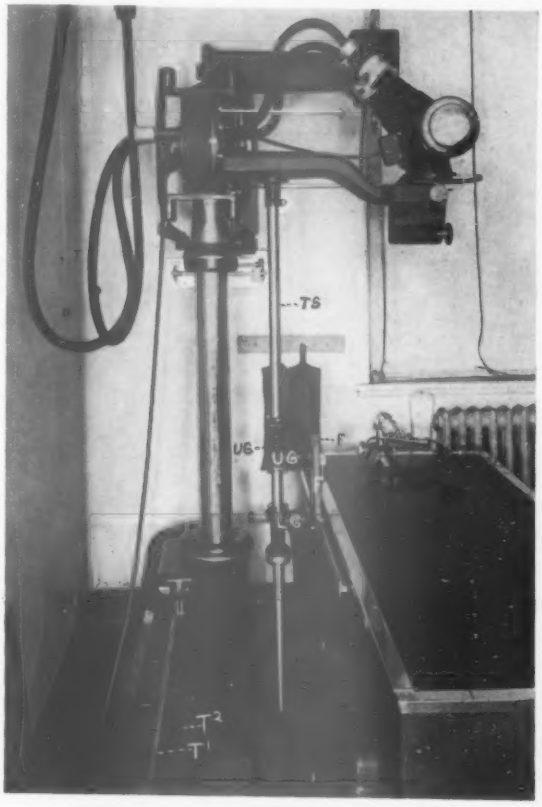


Fig. 2. End view demonstrates attachment of tubular shaft, *TS*, to horizontal roentgen tube support and positions of trombone-action guides. Swivel axis of lower guide, *LG*, is accurately situated in plane of film, and film travel is activated through this guide. The attachment of the upper guide, *UG*, to the fulcrum guide, *F*, is shown. The tube stand travels longitudinally along tracks T^1 and T^2

INDEX TO ABSTRACTS

ROENTGEN AND RADIUM THERAPY

Vonessen, A.: Contribution to the clinical symptomatology and radium therapy of plastic induration of the penis 640

Warren, S., Meigs, J. V., Severance, A. O., and Jaffe, H. L.: The significance of the radiation reaction in carcinoma of the cervix uteri 641

Bering, F.: Roentgen rays in the treatment of progressive paralysis 641

Maderna, C.: Roentgen therapy and chemotherapy of pemphigus 642

Giordano, G.: Our results in radiotherapy of lymphogranuloma 643

MISCELLANEOUS

Calchi-Novati, G., and Rocchini, G.: Recent research on the effect of short waves on renal function 643

Cova, P. L., and Tempini, G.: Experimental study of roentgen anatomy of the extrahepatic bile tracts 643

Windle, W. F., Becker, R. F., Barth, E. E., and Schulz, M. D.: Aspiration of amniotic fluid by the fetus 644

Brunetti, L.: Recent developments of effect of tangency and of principle of psychophysical relativity 644

ABSTRACTS OF ROENTGEN AND RADIUM LITERATURE

Vonessen, A. Beitrag zur Klinik und Radiumtherapie der Induratio penis plastica. (Contribution to the clinical symptomatology and radium therapy of plastic induration of the penis.) *Strahlentherapie*, 1940, *67*, 63–68.

Thirty-one cases of plastic induration of the penis were observed by the author between 1931 and 1939. The average age of the patients studied was fifty years. Over half of the patients were in the fifth decade. Sixteen patients were between fifty and sixty years of age, 7 between forty and fifty years of age, 4 between sixty and seventy, 3 between thirty and forty, and 1 between twenty and thirty. The oldest patient was sixty-two and the youngest twenty-eight years of age. The indurations varied in consistency between average firmness and bony rigidity. The length of the indurated region varied between 0.5 and 6 cm. and its form was variable. In 8 cases a roentgenographic study was made and in 3 of these calcium deposits were found in the form of linear structures, while in 2 the calcium deposits were in the form of perforated plates. Most frequently the middle third of the dorsum was affected; in 4 cases the induration was situated directly below the glans. In 2 cases it was situated on the lateral sides of the corpus cavernosum; in 6 cases the region of the radix was the seat of the affection and in one case the induration extended from the glans up to the dorsum. In nearly all cases there was no pain on palpation. In 2 cases slight tenderness was present. In nearly all cases the onset was sudden. In only a few cases was coitus painful. Depending on the seat of the induration an angular kinking superiorly or to the side occurred. The kinking in most cases was so pronounced that coitus was no longer possible. Not in a single case did impotency develop as a result of the induration, although in some cases a state of depression appeared.

The disease presents a pronounced chronic course. When subjective symptoms appear a palpable induration is already demonstrable. Most patients report to the clinic weeks or months after the appearance of the induration while some only after a year or two. Nine of the patients studied were previously treated, 3 by roentgen irradiation, one with diathermy and

radon salve, one with turpentine injections, one with rheumasan, one with testifortan, one with injections, diathermy and roentgen irradiation and one with local iodine applications. In the case treated with turpentine injections there appeared a transitory regression of the induration but soon afterward the induration reappeared. In the other 8 treated cases no results were obtained.

In 4 of the cases studied a history of trauma was obtained, while in the remainder no such history was obtainable. Histologically the region of the induration consisted of a connective tissue proliferation poor in nuclei and vessels and containing a limited number of elastic fibers. No signs of an inflammatory reaction were present.

All the cases studied by the author were treated by radium therapy. On the basis of the results obtained, the author believes he is justified in concluding that the radium therapy offers the best prospects for a cure or an improvement. A complete cure, that is a disappearance of the subjective as well as the functional symptoms, was obtained only in 2 of the cases, but a considerable improvement was obtained in most of the cases, namely, the process was brought to a standstill, later followed by a regression of the induration and a considerable decrease of the functional symptoms. The improvement may appear anywhere from the second to the tenth irradiation. In some cases relatively large doses of radium were necessary. —*A. Schwartzman.*

Warren, Shields; Meigs, Joe V.; Severance, Alvin O., and Jaffe, Henry L. The significance of the radiation reaction in carcinoma of the cervix uteri. *Surg., Gynec. & Obst.*, Nov., 1939, *69*, 645–647.

The authors present a report based on the histological study of 70 cases treated by the method of Meigs and Dresser. The findings supplement the data on the significance of grading in group prognosis by showing the significance of the histological evidence of radiation change in the tumor cells and the stroma, respectively. The 70 cases when grouped clinically showed 8 to fall in A and B groups and 62 in C and D groups. Graded histologically, 1 epidermoid carcinoma, Grade 1, 25 epidermoid carcinoma, Grade 2, 32 epidermoid carcinoma, Grade 3, 4 epidermoid carcinoma, ungraded, 3 adenocarcinomas, 1 undifferentiated carcinoma, and 4 epidermoid carcinomas biopsied at other hospitals. The histological criteria of the various grade are noted and, in addition, the histological requirements for "a marked reaction" and for "a moderate reaction" in the tumor cells and stroma, respectively. Five tables are presented which correlate the end-result with the following: (1) significance of the extent and histological grading of the tumor before treatment; (2) degree of radiation reaction in the tumor cells after roentgen treatment; (3) degree of radiation reaction tumor cells after roentgen and radium treatments; (4) degree of radiation reaction noted in the stroma after roentgen treatment; (5) degree of radiation reaction noted in the stroma after roentgen and radium treatments.

In summary, the authors find: (1) the histological grade is of less importance in prognosis than the clinical classification; (2) the radiation reaction noted in the tumor cells or stroma is an index to the radioresistant cases and these will die of the carcinoma despite the intensive irradiation. For these cases surgery is advocated. (3) In the absence of radiation reaction in the biopsies there is a strong probability of ultimate death of the patient from carcinoma.—*P. C. Swenson.*

Bering, Fr. Röntgenstrahlen zur Behandlung der progressiven Paralyse. (Roentgen rays in the treatment of progressive paralysis.) *Strahlentherapie*, 1940, *67*, 173–184.

At present malaria is the method of choice in the treatment of progressive paralysis. There are cases of progressive paralysis, however, in which the malarial treatment cannot be carried out; for instance, in the presence of pulmonary tuberculosis, heart diseases, especially those associated with myocardial injuries, etc. In progressive paralysis there are present both inflammatory and degenerative processes, depending on the stage in which the process is observed. In the beginning of the disease inflammatory processes predominate while later degenerative processes dominate the picture. The meninges are infiltrated to a greater or lesser extent and the infiltration consists predominantly of lymphocytes and plasma cells. The vessels of the cortex are in a state of proliferation and their walls are infiltrated and their endothelium is proliferated and swollen. Inflammatory processes are also present in the larger vessels and here also phagocyting elements are found. The condition of the paren-

chyma is dependent on the intensity of the process but is diseased to a greater or lesser extent. The glia, as a rule, is in a state of diffuse proliferation. All parts of the brain participate in the process with a variable intensity. The frontal lobe is, as a rule, most intensely affected and the occipital the least affected, while the affection of the temporal lobes varies. Spirochetes are demonstrable in the parenchyma as well as in the vascular walls and in the meninges. They are found predominantly in the regions which are most intensely affected. Roentgen irradiation of patients suffering from progressive paralysis represents a new method of treatment. The effect of the roentgen rays is most pronounced on the lymphocytosis of the spinal fluid. A study of the lymphocytosis before and after treatment carried out by the author in a number of cases revealed here a definite increase or a complete disappearance of the cells as well as an improvement in the colloidal reaction. This improvement in the cytology of the cerebrospinal fluid is accompanied by an improvement in the subjective and objective symptoms.

Originally the treatment was carried out by the author in two sittings; during the first sitting the left temporal and occipital regions were irradiated and after two to three days the right temporal and occipital regions were irradiated. The irradiation in each case was given with a dose of about 80 per cent of a skin erythema dose. In the first cases treated in this manner no unpleasant side effects were observed. In some later cases slight reactions associated with an aggravation of the existing symptoms occurred and in one case a transitory edema of the brain and an increase in the intracranial pressure occurred; in one case the irradiation was followed by death. After this experience the irradiation was carried out with half of the original dose, apparently with satisfactory results. The greatest objection to the irradiation is the unavoidable epilation of the irradiated fields.

In not a single case, with the exception of the one terminating lethally, did a definite aggravation of the condition result from the irradiation. The irradiation is followed not only by a clinical and subjective improvement but by an objective improvement. The colloidal and protein reactions of the cerebrospinal fluid are favorably influenced and the number of cells is definitely decreased. The cases treated in the above manner have hitherto been observed in the course of thirteen months and in all of them the improvement persisted up to this time.—*A. Schwartzman.*

Maderna, Candido. Roentgenterapia e chemioterapia mel pemfigo. (Roentgen therapy and chemotherapy of pemphigus.) *Arch. di radiol.*, May-June, 1939, *15*, 215–226.

In 1931 the author treated 4 patients with pemphigus by roentgen irradiation of the spinal cord and the sympathetic ganglia, associated with arsenobenzol and quinine treatment. They all recovered and in 1936 two of them were seen again and the cure had persisted. Now—in 1939—he has seen a third patient—a woman of forty—and she also has remained in good health and there has been no return of the pemphigus.

As a result of the first series of irradiations given in 1939 the bullae had disappeared. She was then given three series of injections of neosalvarsan and tablets of valerianate of quinine and after two months the series of roentgen irradiations was repeated. No disturbances were seen after the second series of roentgen irradiations.

In connection with this good result in the treatment of pemphigus, persisting after eight years, the author discusses the probable causes of the disease and the reasons for this result. This patient in the beginning had had disturbances of menstruation and psychic depression with fits of crying without any cause. These psychic and endocrine symptoms had been cured as well as the pemphigus. The author believes that in this disease there are endocrine-sympathetic disturbances and a disturbance of water and chloride metabolism. There was a decrease of chlorides in the blood and urine in the beginning of treatment with an increase of water in the tissues manifested by the development of the bullae. Irradiation with the cross-fire method had stimulated the spinal centers of the sympathetic system and this in turn had stimulated the endocrine glands to normal function. There is no doubt of the great importance of the endocrine glands in neutralizing toxins circulating in the body and the great influence which they have on the skin through the vegetative nervous system, regulating the metabolism of water and salts and thus when disturbed entering directly into the mechanism of the formation of the bullae. When this whole endocrine-sympathetic mechanism is brought

into equilibrium the bullae disappear, and with them the endocrine and psychic disturbances. —*Audrey G. Morgan.*

Giordano, Giovanni. I nostri risultati nel trattamento radiante del linfogranuloma. (Our results in the radiotherapy of lymphogranuloma.) *Radiol. med.*, May, 1939, *26*, 429–433.

The author discusses the results he obtained in 102 cases of lymphogranuloma treated with radiotherapy at the Roentgen Service of the Medical Clinic and the Luigi Galvani Radium Institute at Bologna from January, 1926, to September, 1937.

The technique used in most cases was as follows: 160–180 kv., 2 ma., filter 0.5 mm. copper and 2–3 mm. aluminum. Focus-skin distance 50 cm. for superficial localizations and 30–40 cm. for deep ones. Dose per treatment 200 r in air; for the last two years the dose per treatment was increased to 250 r in air. In some cases that had become resistant to roentgen rays or because of the great extent of the disease he used external local radium treatment or general roentgen irradiation at a long distance by Palmieri's method of superteleroentgen therapy. The immediate results in these cases were satisfactory but they were temporary.

His results were very good; 45 per cent of the patients were alive at the end of three years from the beginning of treatment; 21.6 per cent lived for more than five years and 18.9 per cent were still able to continue their usual work after five years.—*Audrey G. Morgan.*

MISCELLANEOUS

Calchi-Novati, G., and Rocchini, G. Ulteriori ricerche su funzionalità renale ed onde corte. (Recent research on the effect of short waves on renal function.) *Radiol. med.*, Feb., 1939, *26*, 122–129.

About two years ago the authors studied the effect of short waves applied over the kidney region on kidney function. They used the phenolsulphonephthalein test and the water test they found that the amount of phenolphthalein excreted in a given time was decreased thalein excreted in a given time was decreased by about 20 per cent after the application of short waves. The excretion of water was markedly decreased by the short waves. There was an increase in the percentage of urea excreted in the urine and a decrease in the total amount and percentage of the chlorides excreted. These findings did not change appreciably on change in the length of the waves (15 meters and 6 meters). These results were interesting not only in themselves but because they were in contradiction with the effects of diathermy and long waves.

Later Benassi and Migazzo found opposite results; they found an increase rather than a decrease in the amount of water excreted.

The authors, wishing to find an explanation for these different results, found that the position of the body has some effect on diuresis; there is more excretion when the patient is lying down than when he is standing. They found, however, that the chief reason for the difference in results was in the type of electrode used. Benassi and Migazzo had used Schliephake condenser electrodes in place of the plate electrodes that the authors had used. They repeated their experiments using the Schliephake electrodes. They found that with this method the amount of water excreted for the first two hours was somewhat increased and after that it was practically the same as in the controls in some cases and in others increased. Probably the reason for this difference is that with the plate electrodes the heating of the tissues is superficial while with the Schliephake electrodes it is deep.—*Audrey G. Morgan.*

Cova, Pier Luigi, and Tempini, Giambattista. Ricerche sperimentali su l'anatomia radiografica delle vie biliari extraepatiche (esclusa la cistifellea). (Experimental study of the roentgen anatomy of the extrahepatic bile tracts (exclusive of the gallbladder).) *Radiol. med.*, March, 1939, *26*, 226–258.

The authors made a study of the extrahepatic bile tract in 44 human cadavers, in all of which disease of the bile tract had been ruled out. The contrast medium used was a low concentration of barium sulphate containing potato starch. An incision was made in the tip of the gallbladder and the liquid injected through it. In nearly all cases this gave a good visualization of the cystic duct, the hepatic duct with its chief branches, the common duct down to its emptying into the duodenum and in some cases Wirsung's duct and its branches. Roentgenograms and diagrammatic drawings of the emptying of the common duct into the duodenum are given.

The chief controversial point in the study of the extrahepatic bile tract is the presence or absence of the anatomical structures known as the papilla and Bater's ampulla. Busi believes that these structures are only functional and determined by contraction and relaxation of the muscle fibers of Oddi's sphincter.

The authors found that they are real anatomical structures but not present in all cases. They found a true anatomical ampulla in 18 per cent of their cases. In the greater part of the cases the common duct and Wirsung's duct ended in it; rarely it was found in the terminal part of the common duct, while Wirsung's duct had emptied above it. All the other dilatations of the lumen of either the common or the pancreatic duct, or due to the confluence of the two ducts without any distinct ampulla are to be considered pseudo-ampullar dilatations; often it is impossible to differentiate roentgenologically between these various structures.

The papilla is a real anatomical structure and was found in 70 per cent of their cases. They found that sometimes the bile-pancreatic tract may end in the mucosa of the duodenum without any true ampulla, at the bottom of a funnel-shaped extroflexion of the wall of the duodenum. This structure may easily be confused with the image of the ampulla. The author believes that this type of termination of the bile-pancreatic tract was present in 2 cases described by Lindblom, where a bicornuate structure was extruded from the median wall of the descending part of the duodenum; this structure did not have any of the characteristics which would define it as a true ampulla.—*Audrey G. Morgan.*

Windle, W. F., Becker, R. F., Barth, E. E., and Schulz, M. D. Aspiration of amniotic fluid by the fetus; an experimental roentgenological study in the guinea pig. *Surg., Gynec. & Obst.*, Dec., 1939, *69*, 705–712.

Relative to the problem concerning the occurrence of intra-uterine respiratory movements of the fetus, the authors present a summary of their own experimental observations and those reported in the literature. Despite conclusions of other writers, the authors maintain that the respiratory-like movements of the guinea pig fetuses in utero are not maintained when normal physiological conditions prevail. Further evidence to supplement this view forms the thesis of the article. Granted the premise that these respiratory-like movements do occur toward the end of gestation, the authors attempt to answer the question: "What is the evidence that the fetus aspirates the amniotic contents?" Thorotrast or thorad was introduced into the amniotic fluid about the heads of fetal guinea pigs in late prenatal life under normal and abnormal physiological conditions. The abnormal state was brought about by producing an anoxemia in the maternal circulation through the placenta. Observations under physiological conditions in 20 instances revealed no evidence of aspiration. In the presence of experimental anoxemia, however, the observation of fetal respiration could be excluded in only 2 of 25 instances. In the same group the evidence of aspiration was definite in 9 and questionable in 2 of the 25 observations. Judging from these results they believe: (1) that aspiration of amniotic contents does not occur normally in the guinea pig but it may be brought about under conditions of asphyxia; (2) that not all respiratory-like fetal movements produce aspiration of amniotic fluid. Interpreting these results in the possible similarity of human fetal respiratory behavior, the implication is that asphyxial types of anesthesia could lead to prenatal aspiration of amniotic contents.—*P. C. Swenson.*

Brunetti, Lodovico. Ulteriori sviluppi dell'effetto tangenza e del principio di relativita psico-fisica. (Recent developments of the effect of tangency and of the principle of psycho-physical relativity.) *Radiol. med.*, June, 1939, *26*, 550–560.

This is a detailed mathematical discussion of the tangency effect which is an optical manifestation of the bi-tri-dimensional condensation of a layer struck tangentially by the bundle of roentgen rays, consisting of an image of stripes or bands of hypo- or hypertransparency, of a thickness not less than the thickness of the layer which generates it. The roentgen image is influenced, however, by psychic factors. The image is interpreted according to the observer's ideas of the anatomical conditions. For instance, in a roentgenogram of long bone the observer sees a marrow canal surrounded by a denser cortex, even though physically the image of the marrow canal is denser than that of the cortex. This theory of psycho-relativity is discussed at great length.—*Audrey G. Morgan.*

Bachrach

MERRILL C. SOSMAN

President of the American Roentgen Ray Society

1940—1941

UNIV. OF MICH.